“Echoes in Education:”

Re-classifying classroom acoustics in traditional and modern learning environments in New Zealand

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Ka aroha tino nui ki a koe.

ABSTRACT

AIMS

This project focused on the acoustic characteristics in a mixture of Modern Learning Environments and Traditional NZ classrooms currently in use for educating primary school children. The aim was to evaluate these two styles of classroom against three different scales of acoustic recommendations including the NZ Ministry of Education, the Australian, Department of Education (NSW), and an International scale based on research by Dr Kiri Mealing (2016). The implications of these findings will be discussed in relation to the impact they have on children's access to sound, ability to hear well, and thus learn effectively. A key focus of the research will be the potential implications of acoustics for inclusive education regarding children with additional learning needs especially hearing impairment.

METHODOLOGY

Eleven Modern Learning Environments and eleven traditional cellular classrooms will be evaluated for their acoustic properties while they are both occupied, and unoccupied by students. Four acoustic parameters will be measured using an App which has been recently designed by the National Acoustic Laboratory in Australia especially for assessing classroom acoustics.

RESULTS

Evaluating the classroom acoustic performance over four parameters rather than just two yields a more accurate profile of the true functional acoustic environment each space presents. In the final analysis, only 5 of the 11 (45%) MLE, and 7 of the 11 (64%) TRAD classrooms met all 4 of the recommended acoustic parameters including ANL, RT, BNL and STI to a level which was deemed acceptable. **Just, 12 of the total 22 (55%) classrooms surveyed in this study met all 4 of the overall INTERNATIONAL recommendations.** A significant co-relation was found between BNL and the number of children in a teaching space.

CONCLUSIONS

The mixed results present in this study suggest that there is plenty of scope to improve classroom acoustics especially for the most vulnerable young learners. The unsatisfactory acoustics present in this investigation are of concern not only to researchers, and academics, but also cohorts within the community. Many sector groups have long called for improvements. It is to be hoped that school boards, teachers, parents and audiologists will soon be equipped with the recently developed “SoundOut” Classroom Acoustics App.

The scientists at NAL in Australia, specifically designed the App to measure both occupied and unoccupied acoustics with a view to enabling and empowering these sector groups to gather their own data towards mitigating poor acoustics in educational settings. It is anticipated that these findings may contribute to an argument for a nationwide review of the acoustic properties in some existing classrooms. That is if the spaces in which <u>all</u> New Zealand children learn, are to be brought up to the specifications within the MoE guidelines. This research supports international recommendations for “optimal” rather than merely “acceptable” acoustics as the benefits for both students and teachers are substantial.

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ABBREVIATIONS

AL	Activity Limitation
ASHA	American Speech and Hearing Association
dB	Decibels
CHL	Conductive Hearing Loss
DQLS	Designing Quality Learning Spaces
FFR	Frequency Following Response
HI	Hearing Impairment
IQ	Intelligence Quotient
MLE	Modern Learning Environment
MoE	Ministry of Education
NZ	New Zealand
OM	Otitis Media
OME	Otitis Media with Effusion
PDF	Portable Document Format
PR	Participation Restriction
RT	Reverberation Time
SFA	Sound-field Amplification
SNR	Signal-to-Noise Ratio
STI	Speech Transmission Index
TRAD	Traditional cellular classroom

DEFINITIONS of educational terminology

It is important to note that the term Modern Learning Environment (MLE) is unique to New Zealand (NZ). Recently, the NZ Ministry of Education (MoE) has begun to refer to MLEs as innovative learning environments, (ILE) as this term is deemed more consistent with international usage. The terms ‘open-plan classroom’, ‘innovative learning environment’ or ‘21st century learning environment’ may be found throughout the duration of this thesis, and each are analogous with the definition of a MLE.

Break-out spaces	Small spaces which are used for smaller groups of students who are all focussing on the same task.
Didactic teaching	Teachers provide students with the required theoretical knowledge through face-to-face direct instruction. This is the typical method of instruction in single-celled classrooms.
Factory-style learning	Where all students learn the same things, at the same time, in lock-step fashion (Osborne, 2013).
Incidental learning	Not typically classroom-based or highly structured. This occurs because of other activities such as interpersonal interactions, trial and error experimentation or accomplishing tasks. It is the desired method of instruction in MLEs.
Knowledge-based economy	“Production and services based on knowledge-intensive activities that contribute to an accelerated pace of technological and scientific advance as well as equally rapid obsolescence” (Powell & Snellman, 2004, p. 201).
Modern Learning Environment	An environment that is capable of evolving and adapting as educational practices evolve and change therefore remaining modern and future focused. The term ‘MLE’ is analogous with ‘innovative learning environment’, ‘open-plan classroom’ and ‘21st century learning environment’.
Single-celled classroom	Traditional primary school classroom, set out as a learning space suitable for approximately 30 students. These are also referred to as ‘traditional’ learning environments. (TRAD)

Introduction

In New Zealand, the Ministry of Education has capital stock of approximately 30,000 buildings over 2,100 schools (Ministry of Education 2016). The Ministry of Education requires schools to include "Modern Learning Environments" as part of their 10-year property plan. This plan forms part of the MoE funding cycle known as the 5-year agreement which entitles a school to apply for capital funding (Ministry of Education, 2014a). The Ministry's definition of a MLE is as follows "*a flexible quality learning space, including adequate acoustics, lighting, heating and ventilation"* (Ministry of Education, 2014a). These Modern Learning Environments are deemed *"to provide teachers with the ability to use innovative and imaginative teaching practices that are not the traditional classrooms of the past"* (Ministry of Education, 2014b). The regulations were developed to ensure that educational spaces evolve to reflect modern teaching and learning pedagogy, and that they remain built to a high standard of acoustic performance (Ministry of Education, 2016).

Research indicates that a MLE is an amalgam of tangible and intangible elements (Bisset 2014). The tangible aspects are typically conceived as stylised buildings, fashionable furniture, and high end technology. Whereas the intangible elements are largely pedagogical and revolve around a shift from a "teacher-centric" scenario to a "student-centric" focus. In other words, the teacher becomes more of a facilitator working alongside students. That is, their role is to encourage children to have increased ownership of their learning style, by encouraging flexibility of place <u>and</u> pace of knowledge acquisition. Team teaching and working collaboratively are both encouraged and enhanced by this pedagogical paradigm shift (Campbell et al 2013). It is further driven by the presence of technology and a cluster of diverse learning spaces. Therefore, the theoretical concept of a MLE involves the nexus of three elements: - Pedagogy, Technology, and Space (Bisset 2014).

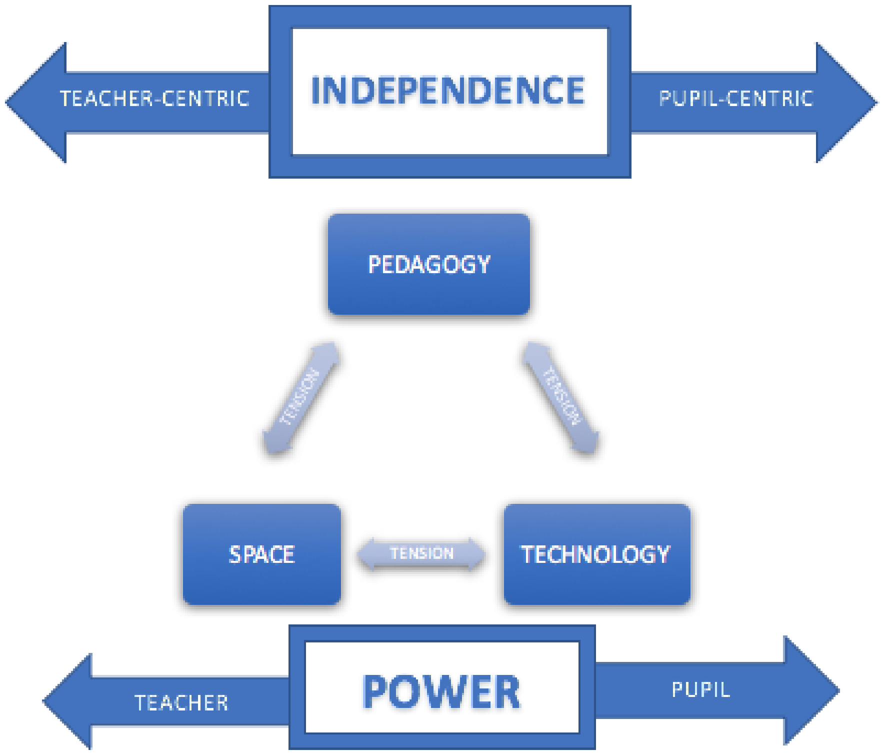


Figure 1: The interrelationship of pedagogy, space and technology in MLE (adapted from Radcliffe's "Learning Environments Evaluation Framework" 2009)

Sceptics of MLE view them as a return to the experimental "open plan" classrooms of the late 1960's-1970's (Parnell & Proctor 2011). It was found that these spaces were not advantageous when teaching specialised subjects, there were concerns around noise levels, distractions and class sizes (Wilson 2015). The suspicion is that "*open plans are cheaper to construct than segmented plans and can be supported for budgetary rather than pedagogical reasons"* (Dovey & Fisher 2014). Added to this is the paucity of evidence in support of MLE's and the associated change in teaching style delivering any positive contribution to student achievement (Wilson 2015). A substantial meta-analysis conducted by NZ Professor Hattie in

2009 concluded that *"the underlying principles of Direct Instruction place it among the most successful outcomes for students"* (Wilson 2015) There is some consensus among researchers that adjustments to the architecture alone will not facilitate the paradigm shift desired by the MOE even if considerable resources are deployed to support teachers through this transition (Parnell & Proctor 2011; Campbell et al 2013; Bisset, 2014).

Essentially, a MLE is an adaptable area which *"relies on the presence of large standardised spaces, which can be divided-up with moveable partitions"* (Parnell & Procter, 2011). The MOE endorses these flexible spaces because they *"encourage independent learning, small group work and teachers working co-operatively across spaces"* (MOE 2014a). Much of the drive to incorporate MLE into schools is due to the rapid increase in digital technology in the classroom. The most significant tool which assisted in collaborative learning was the tablet or laptop which many secondary students and an increasing number of primary students use as their principal method of note-taking and learning (Grayson 2010).

During the preceding thirty years, a body of evidence has accrued which indicate poor classroom acoustics negatively impact educational outcomes, especially reading and language. (Ronsee et al 2013; Lubman, 1997; Crandell & Smaldino, 2000; Nelson 2000; Wilson 2002). Two of the most salient aspects of room acoustics are the Reverberation Time and the ambient noise. In simple terms: echoes and environmental noise. RT is a consequence of the physical characteristics of a space; it increases linearly with the volume of the room and it is inversely connected to the degree of sound absorptive material in the vicinity. The longer the original signal persists within a confined area the greater the chance it will overlap with the direct signal, and mask it in some way. In classrooms speech is usually the most important signal; if the room contains numerous hard surfaces these increase the RT and interfere with the intelligibility of the spoken word.

Reverberation time by definition is the duration it takes for a signal to decrease in level by 60dB (RT60) following the cessation of the original signal. It is calculated using the Sabine formula (RT60=kV/A). Where (V)= room volume, and (A)= the equivalent area of perfect absorption, and k= constant of 0.161 metric units. (Knecht et al 2002; Crandell & Smaldino 2000). Research conducted in NZ during the mid 1980's found an average RT of .73 and .76 seconds across two rooms. A decade later five school rooms were tested and the RT were between .37 and .56 seconds. Studies conducted in Europe and America around the same time yielded RT from 0.4-1.2 seconds (Wilson, et al. 2002). In a space where primary school children are taught, the research consensus suggests that a reverberation time of 0.4 seconds is preferable (Seep, et al. 2000; Wilson, et al. 2002).

The current recommended design sound levels and reverberation times for building interiors is set at of 0.4-0.5 seconds by the Australian and New Zealand Standards Association (AS/NZS 2107:2000). Additionally, in 2016, the Ministry of Education, in association with the Building Research Association of New Zealand (BRANZ) has published its own building guidelines document known as: Designing Quality Learning Spaces, or the DQLS version 2. The Acoustics section of this infrastructure paper suggests a range of RT's from 0.4-0.8 is acceptable, depending on the "nature of the learning space" (pg. 13). For example, a cellular classroom is expected to conform to an RT value of 0.4-0.5 whereas a "flexible learning space" allows for RT values ranging from 0.5-0.8. Gymnasiums have the highest allowable RT range from 0.8-1.5 seconds.

The second factor identified as impacting negatively on speech understanding and hearing in a classroom is 'ambient noise'. It is defined as "any undesired sound that impedes what a child wants, or needs to hear" (Knecht et al 2002). Ambient noise can be further classified as either internal noise (heating, projectors, air conditioning) or external noise (traffic, aircraft, lawn mowers, adjacent classroom noise). Earlier research conducted in NZ indicated unoccupied classroom ambient noise levels in the vicinity of 28-60dBA (Wilson 2002). Currently, the AS/NZS 2107:2000 states that a classroom should have a satisfactory unoccupied noise level of 35dBA and maximum of 45dBA. Controlling for background noise in a teaching space is vital, as it has a direct impact on the signal-to-noise ratio. The signal-to-noise ratio identifies how loud the desired audio is compared to the background audio; hence it provides a good indication of how clear a sound is for the listener. When measured at a pupil's ear, the signal-to-noise ratio should be above +15dB for a child at primary school (Wilson, et al. 2002).

New Zealand is not alone in this educational revolution; Australia too is undergoing a similar process in its teaching spaces and teaching practices, which have been dubbed "21st learning environments". It is the intention of this research paper to focus primarily on the acoustic aspects of these spaces, as these represent an objective measure of MLE which can be compared to traditional cellular rooms. Specifically, the reverberation times and ambient background noise encountered in these two different spaces. The measurements will be obtained in order to compare the results to the specifications outlined in the NZ building code, and 2016 DQLS guidelines. Measurements will be made under two conditions. Firstly, unoccupied classrooms will be measured as the acoustics are largely the consequence of designers and architects. Secondly, occupied rooms will be measured, as they are controlled to a greater extent by the teachers and pupils in those spaces.

The ensuing literature review is presented in a narrative form, which is one of many suitable organisational methodologies for an academic dissertation (Ferrari, 2015).

LITERATURE REVIEW

2.0 Official Definition of a Modern Learning Environment

On the Ministry of Education official website (2015b) "Modern Learning Environments" are characterised thus: *"A learning environment may be understood to be the complete physical, social and pedagogical context in which learning is intended to occur"*. Further to this, a modern learning environment as such reflects and supports what is current in terms of pedagogical practice. Contained within this definition is the notion that the space is contemporary and focused on the future.

2.01 Genesis of MLE

In 2010, the Ministry of Education outlined adjustments to the two funding streams available to schools for "health and safety", "essential infrastructure /projects" and "Modern Learning Environments". Entitled the Ten-Year Property Plan (10YPP), and the Five-Year Agreement (5YA). The scope of these documents outline the genesis of MLE by outlining the steps required by schools to incrementally upgrade their teaching and learning environments to standards specified in a paper titled Designing Quality Learning Spaces (DQLS,2016 v2). These improvements were to be completed by 2020, and cover aspects of teaching spaces including, lighting, ventilation, heating and acoustics (Wilson 2015). Across Aotearoa/New Zealand, there are a total of 2,100 school campuses which house a total of around 30,000 buildings (MoE, 2016). This infrastructure is managed at three levels. Initially, by the local Board of Trustees, secondly on a regional basis by Ministry of Education 'Delivery Managers', and ultimately at a national level by the Ministry of Education. (MoE, 2016). The requirement to upgrade and modernise both the teaching spaces and the pedagogical practices has been foisted on schools and communities irrespective of their viewpoint regarding the proposed changes (Benade, 2015).

These conceptual, pedagogical and spatial changes have been termed MLE in NZ, elsewhere in the world, they are called Innovative Learning Environments (ILE), Flexible Learning Environments (FLE) New Generation Learning Environments (NGLE) or 21st Century Learning Environments, (Wilson 2015)

Some of the initial enthusiasm for MLE can be traced back to a series of research projects undertaken by the Organisation for Economic Cooperation and Development (OECD, 2008). This is a forum consisting of thirty-four democratic governments, plus seventy non-member economies which work cooperatively to develop policies which encourage economic growth, sustainable development and prosperity. Subsequently, the MoE rapidly endorsed these new educational structures/pedagogies and commissioned a study of its own. Entitled; 'Supporting Future-oriented learning and teaching – a New Zealand Perspective' (Bolstad et al 2012). The imperative driving these upgrades can be partially attributed to this report. The goal of the study was to investigate international changes and principles of forward thinking educational practice with a view to preparing young New Zealanders' for what has become known as the 'knowledge age'. For this to occur, learners will need to be:

"confident, connected, actively involved lifelong learners". (MoE 2007, pg. 8)

2.02 Evolution of Modern Learning Environments

One of the chief criticisms to arise from the Bolstad report concerned the educational model pervasive throughout Aotearoa /New Zealand at the time. The curriculum and pedagogical practices of the time were attributed to an "industrial model' of education. That is, the system emphasised the communication of knowledge through a teacher-centric process, delivered in a factory style setting (Wilson 2015). Effective learning was a consequence of 'direct instruction' and there was a pronounced focus on the rote learning of material (Osborne, 2013). Allied to this notion was the 'factory-style' practice, of teaching an entire class identical information simultaneously. To this end the stock of school buildings were perfectly suited to this style of teaching. Rooms were typically arranged to facilitate this presentation of knowledge, with a teacher at the front adjacent to a blackboard, while students sat in rows at desks. This style of teaching has been termed a 'Stand and Deliver' method, and the spaces it occurred in were traditionally 'single-celled' entities, i.e. classrooms (Bolstad, 2012, Wilson 2015).

As a consequence of massive scientific and technological developments, this mode of information delivery was viewed as increasingly outdated. The industrial model of education was no longer seen as delivering the requirements of a global knowledge-based society or workforce. (Bolstad, 2012; Wilson 2015).

2.03 The Ministry Position

Over time the Ministry of Education has transitioned the requirements of the national curriculum document from being a purely didactic uniform set of learning goals, to one which is essentially a framework for inquiry (Wilson, 2015). Communities and their associated families have been encouraged to participate in the development of relevant curriculum plans. These initial shifts away from the regimented delivery of education began in 1992, and were followed in 2001 by more flexible units of competency known as the National Certificate of Educational Achievement (NCEA). These new standards were created, ostensibly to allow greater diversity of pathways to achievement for students, but also to offer a wider scope of interests, not just academic subjects to be pursued by learners. Subsequently, there have been several different revisions of this document. The most recent of which is known as the National Qualification Framework (NQF). The long-term vision is for future assessments to be undertaken online, anywhere, at any time. Thus, the Ministry of Education's overarching assessment framework is based around flexible, individual, diversified learning pathways (Wilson, 2015). Modern Learning Environments are seen as crucial to the delivery of these outcomes. In part this is due to the viability of connecting learning and evaluation to real-world contexts like fieldtrips or experiments, or the inclusion of group work for evaluation. (Wilson 2015). In the Ministry of Education puts it thus: "*the spaces exist to support an educational purpose. Good spaces enable, but do not guarantee good educational outcomes. Poor spaces will adversely impact educational outcomes." (MoE 2015b)*

2.04 Features of Modern Learning Environments

The key concept of MLE's is flexibility. It is the notion that these spaces are adaptable, that is they are fit for purpose in the present context, but also capable of being adjusted for future pedagogical changes. Thus, they may be libraries, scientific laboratories, gymnasiums, tutorial hubs etc. Whilst MLE may be conceived of as replacing traditional classrooms, they are perhaps better classified as spaces where learning occurs. Some assert that these spaces enhance learning by creating a more 'home-like' environment which increases a young learners sense of security when compared to the more authoritarian style of traditional cellular classrooms (Maclure, 1984). Several universal features commonly typify these new innovative spaces, including: access to resources, flexibility, and openness.

RESOURCE ACCESSIBILITY

Much of this drive for flexibility has been made possible through the advancement and availability of portable technology in schools. By pooling access to resources, particularly digital technology several classes can utilise the facilities at any one time. Having a classroom devoid of technology is simply not an option in today's educational environment (Wilson, 2015). A common layout is for a centralised area which houses hard wired technology, which is accessible when students require it. This is usually complimented by wireless technology which is more mobile and can be utilised by students anywhere within the MLE. Other resource specific areas which frequently surround the technology hub include spaces for activities such as reading, presentations, group work or project spaces. (Osborne 2013). The ready availability of technology equips students with the ability to make global connections, and to enhance aspects of their own learning (Osborne,2013; Song 2014). Technology has been transformational, not only in the provision of instant access to information, but also in the mode in which students take notes. This is becoming a universal trend for many secondary schools, and a rising number of primary schools are also following suit with Bring Your Own Devices (BYOD) policies. This mobile technology is viewed as perhaps the singularly most effective tool in group work and collaborative learning. (Grayson, 2010). The presence of such powerful technology does come with the caveat of mindfulness regarding safety around online resources (Madden et al 2012)

FLEXIBILITY

This fluidity extends to the mode of teaching available to students. Teachers are able to combine classes together, and effectively "team teach" which enables individual teachers to share their strengths across a wider number of pupils. These classes can also be divided up into smaller groups and arranged throughout the open space depending on their specific areas of study. These opportunities for cross-curriculum collaboration are proposed as a further benefit of the Modern Learning Environments. A key concept of these new teaching spaces is the absence of "ownership" of particular zones (Shank, 2005). Conceptually, this means that in any given day, a learning space could be used by a variety of teachers, each of whom may be specialists in different subject areas. There also exists the potential to extrapolate this concept to multi-level teaching. That is where students are formed into clusters and taught based on their appropriate curriculum abilities rather than their chronological age. The intention is to create spaces that encourage peer interaction within and across year groups, and promote closer working relationships between staff and students and enable particular coursework activities – such as group work (Waldock & Rowlett, 2017; Bisset, 2014).

OPENNESS

The physical features of MLE's tend to endorse open spacious architecture, with limited physical barriers between spaces, and a preference for the use of transparent materials such as glass when these are required. Adjunct to the physical "openness" afforded by MLE's is the notion of more "open" teaching practices. MLE have been credited with the potential to 'de-privatise practice' (Campbell et al, 2013). That is the idea that communal teaching will enable opportunities for personal and professional development as a consequence of observing other professionals engaged in the practice of educating students. (Osborne 2013). It is envisioned that this sharing of knowledge will have positive repercussions within the teaching fraternity by enhancing a sense of collegiality, and reflective practice within the profession (Nieto 2003). Another potential advantage offered by MLE occurs during the induction of new young teachers. Their placement alongside experienced teachers is likely to create a supportive environment, and one where several teachers are readily available should a problematic situation arise (Bisset, 2014).

One of the principle aims of MLE is to educate children in a manner which is complimentary to the dynamic, fluid, and techno-centric world they will inhabit (Jankowska & Atlay, 2008) However a caveat to this vision of transformational education is the adequate provision of professional support and training for teachers to enable them to utilise these new facilities (Campbell et al, 2013). The presence of modern learning environments alone will in and of itself not bring pedagogical change to the style of teaching occurring within them. In order for these spaces to be utilised in the intended manner substantial resources must be deployed to encourage and develop more flexible teaching practices (Parnell & Proctor, 2011). These new educational spaces could be considered more successful when both teachers and students were supported to experience ways in which their new environment could facilitate optimal outcomes. Prioritising the design of learning spaces around the needs of the students contrasts with the traditional industrial style of education which prioritised the needs of the teacher, however innovative learning zones endeavour to ensure that these spaces are mutually beneficial to both parties (Parnell & Proctor, 2011; Osborne, 2013; Jankowska & Atlay, 2008; Wilson & Randall, 2010).

2.2 Variations differentiating MLE from cellular classrooms

2.21 Early models of education in Aotearoa/New Zealand

The traditional model of a classroom in this country has existed since the original Education Act became law in 1877. This document enshrined the guaranteed right to a free, secular education for all children throughout Aotearoa/New Zealand from the age of seven through to thirteen years. Attendance was standardised and compulsory nationwide. This was education for the masses delivered via an industrial style model (Wilson, 2015). It was designed to produce large quantities of people with rudimentary competencies in reading, writing, and arithmetic who would be suitable for factory-style work.

Teaching spaces reflected this industrial approach as they were typically arranged into unitary cellular classrooms with a series of desks in rows which faced the front of the room where the teacher stood in front of a blackboard instructing pupils (Dovey & Fisher, 2014). Classrooms were isolated rigid spaces where expert teachers imparted knowledge behind closed doors (Bisset, 2014). The transference of information was conducted in a hierarchical manner from the teacher to the pupils consistent with the teacher-centric pedagogy of the time. Strict discipline and standardisation were the prevailing ethos. There was an expectation that students would all learn the same material, at the same time, at the same pace (Horn & Evans, 2013; Dovey & Fisher, 2014). This passive model of learning was termed Behaviourism, and it is predicated on the notion that a student is a passive recipient of material (Dewey, 1933). The learning process was shaped through repetition, followed by a series of positive or negative reinforcements, known as 'programmed instruction' (Field, 2007). This extended to the assessment regime, which was entirely based on an individuals' work, rather than any collaborative effort. The style of testing was equally, formulaic, and uniform.

2.22 Current models of education in Aotearoa/New Zealand

As the nineteenth century progressed three notable educationalists in the form of Dewey, Piaget, and Vygotsky challenged the status quo, and offered up alternative models of education. Firstly, John Dewey, the American philosopher/educationalist railed against the passive depiction of the learning process. Instead, he depicted it as an active process which required the cognitive and physical involvement of individuals in the successful acquisition of knowledge

(Dewey, 1933). The second, alternative promulgated by Jean Piaget, the Swiss psychologist who specialised in child development revolved around the concept of assimilation, i.e., the idea that individuals adapt to their particular environment as a consequence of cognitive schemes, and that this process is constantly in a state of flux due to the experience of new events or information. (Pardjono, 2016). Thirdly, Lev Vygotsky a Russian psychologist/educationalist expanded on the previous two experts by surmising that learning occurred in a ‘zone of proximal development’. That is the concept that intellectual progress occurs when guidance is provided at the appropriate time to facilitate development during the problem-solving process (Pardjono, 2016).

The seeds of a modern style of learning essentially germinated from a combination of these three educational theorists. Their aspirations for education are encapsulated in both the current modern pedagogies, and the functional goals of modern teaching spaces. The emphasis is on reciprocal communication between teachers and learners, where both groups are conceived as senders and recipients of information. Whereby the teacher is tasked with facilitating both individual and collective solutions to problems by utilising creative and social solutions in the decision-making process (Osborne 2013).

2.3 Modern Pedagogy = Increased Incidental learning

Modern Pedagogy still utilises direct instructional teaching from the teacher, however there is an increased emphasis on incidental learning, that is often peer-focused, and indirect (Nelson & Soli, 2000). Teaching using an incidental model requires interactions which are both verbal and social, frequently this involves participation in small groups which provide the opportunity for what is termed ‘passive’ or ‘secondary’ learning (Nelson & Soli, 2000). Essentially, this is the assimilation of information as a result of listening to the verbal interactions in the child’s environment. This process raises a child’s awareness of social cues in their immediate environment (Flexer, 1994). It also facilitates more meaningful communication due to advances in language and literacy skills generally (Nelson & Soli, 2000).

The rapid advancements in technology, along with the significant economic and social restructuring which has occurred since the industrial age have all combined to impact on the nature of teaching models which are currently in vogue. In particular, the heightened fluidity and complexity of the modern world has instigated considerable re-thinking about the function of education (Fraser & Hill, 2015). As yet the move to incidental teaching pedagogies, have not altogether been synchronised with Modern Learning Environments. It has been suggested, that some of this reticence has been as a consequence of the paucity of evidence in support of their efficacy (Benade, 2015)

New Zealand appears to be in-step with international pedagogical trends as it has moved away from a 'passive/recipient' model of student learning to one which is more dynamic and interactive. Although other countries may still spend proportionately more time in didactic teaching than is currently practiced here in New Zealand (Wilson, 2000). Consequently, much of what primary school children learn is a function of their ability to listen and hear easily.

2.4 Optimal listening environments

The ideal educational environment for a child is one in which the child has a clear acoustic signal from the teacher to ensure good speech intelligibility, and ease of listening (Wilson et al, 2000). Youngsters at primary school spend around four to five hours a day in a classroom. Sixty-nine per cent of this time is allotted to group work, or work on the mat, leaving just twelve per cent to specific didactic teaching (Valentine, et al 2002). Knowing this, emphasises the need for good acoustic environments which facilitate the comprehension of information relayed to children by the teacher. Naturally, as their language abilities improve, so too, does their passive learning (Ling, 1988). This is particularly significant for the youngest of students as their reading skills are yet to fully develop, normally this skill is well established by a child's fifth year at school (Matkin, 1996).

As the Ministry of Education strives to ensure that both pedagogical practices and learning spaces are simultaneously fit for purpose now, and into the future, it seems likely that children and teachers may be negatively impacted by the almost inevitable increase in background noise levels caused by larger numbers of children occupying non-traditional learning spaces (Bolstad et al., 2012). This phenomenon has led to the description of these new spaces as "modern listening environments" (Wilson et al, 2018).

2.41 Sub-optimal environments & background noise

The imperative for primary school aged children (5-11years) to have clear unimpeded acoustic signals arises from the physiological processes associated with the development of language. Initially, this requires the recognition of speech sounds, which subsequently require accurate processing and finally the formation of stable consistent auditory memory related to these specific speech sounds (Moore et al, 2011). If these sounds are unstable, fluctuate, or are difficult to discern this can lead to auditory processing difficulties for the child. Excessive background and environmental noise are undesirable impediments to comprehension of speech. One of the ensuing consequences of this, can be language difficulties (Evans & Maxwell, 1997; White-Swoch et al., 2015; Crandell & Smaldino, 2000). Detrimental effects from noise may also impact negatively on a child's reading and language comprehension (Klatte et al, 2010; Maxwell & Evans, 2000; Ronsse & Wang, 2013) Other research espouses the adverse effects of noise in relation to the psychosocial and psychoeducational achievement of children as a consequence of its impact on their cognition, and ability to concentrate (ASHA, 2005; Crandell & Smaldino, 2000; Shield et al 2010; Smith A.P., 1991). In quasi-experimental studies the result of chronic exposure to noise, especially reverberation in classrooms and other indoor noise was associated with poorer performance of the children in verbal tasks (Klatte et al, 2013) Recently, more evidence has emerged which indicates that noise from within the classroom impacts negatively on letter, number, and word recognition (Lundquist, Holmberg & Landstrom, 2000; Maxwell & Evans, 2000; Shield & Dockrell, 2008).

Younger children are particularly susceptible to interference from noise (Mealing, et al, 2015; Buss & Leibold., 2017). Essentially, this is due to the immaturity of their auditory systems. At a neurological level the cortical connections in the brain have not yet fully developed and dispersed throughout the various areas of the brain involved in the processing of speech and language. Cognitive neuroscience and neuroimaging have demonstrated that this process begins in early childhood and is not fully formed until early adulthood around 20 years of age. (Johnson et al., 2009). Interestingly, these findings agree with recent studies involving students in secondary schools who also report being negatively affected by noise to varying degrees (Brannstrom, et al, 2017; Persson, et al 2015).

2.42 Speech as noise

It is well known that children typically perform worse than adults on a variety of masked speech perception paradigms, but this effect is especially noticeable when the masker itself is also composed of speech (Buss & Leibold., 2017; Corbin et al, 2016; Wightman & Kistler, 2005). To recognise speech-in-speech it is thought two processes are involved. The first involves the separation of the target speech from the masking using selective attention, (Leibold, 2012). The second requires some connection between frequency and time, often termed ‘auditory stream segregation’ (Sussman et al., 2007). A growing accumulation of reports are demonstrating larger developmental effects for speech-in-speech masking, compared to studies based on generators of other masking noise (Buss & Leibold., 2017; Corbin et al, 2016; Wightman & Kistler, 2005).

This research lends support to the substantial benefits of spatial separation for enhancing speech comprehension in noisy speech-laden environments such as classrooms. This may be particularly relevant as the use of Modern Learning Environments increase nationwide. Given that classes with young children have been shown to have the greatest levels of noise (Jamieson et al, 2004; MacKenzie & Airey, 1999; Wroblewski et al, 2012). It is likely to inform decisions regarding the most suitable age of children who should inhabit these teaching spaces. Perhaps the most salient point to arise from the collective research examining children and excessively noisy environments is the realisation that noise places additional demands on children's listening effort. In particular, the unnecessary consumption of cranial resources such as working memory which are diverted from cognitive and language processing (Anderson, 2004; Ronnberg et al 2008; White-Schwoch et al 2015). Subsequently, this auditory overload, can result in many children simply "tuning out" (Anderson, 2004; Maxwell & Evans, 2000)

2.43 Physiology of speech processing in children

During childhood, youngsters are endeavouring to make sense of their auditory environment by developing exact representations of the various sounds involved in speech and language, and connecting these to meaning. Physiologically, this is a highly-nuanced process which requires complex synchronisation between auditory and cognitive signals, along with working memory (Anderson et al 2013; White-Schwoch & Evans et al 2015). Synchronicity of neural firing is essential for the comprehension of speech in noise. The information which is relayed from the soundscape is multi-dimensional and sophisticated as it includes both spatial and temporal cues. Even the smallest discrepancies in the coding of these messages seem to cause inordinate difficulties especially for young listeners (White-Swoch & Evans et al 2015; Bidelman & Krishnan, 2010; Song et al, 2012). Noise, and reverberation are highly implicated as disruptive factors in this processing (Anderson et al 2013; Fujihira & Shiraishi, 2014; Ruggles et al, 2012).

Researchers investigating neural synchronicity within the auditory system use a process called Frequency-Following Response (FFR). It involves the monitoring of neural activity from the nuclei in the midbrain (Kraus et al, 2000). Aspects of the speech are variously encoded including pitch, along with formant cues pertaining to the identification of phonemes. Included in this data, is information relating to timing cues such as the temporal envelope, and the temporal fine structure (White-Swoch & Evans et al 2015). Three of the most significant aspects of this processing are thought to involve 1) variations in neural firing: 2) timing within the auditory system: 3) detailed processing of consonants (Hornickel & Kraus, 2013; Kuhl, 2004). Of these three factors, research shows that consonants are harder to perceive than vowels in adverse listening environments (Leibold & Buss, 2013; Johnson, 2000). Vowels tend to have fairly steady spectral information, and be of a longer duration, and of a greater intensity. Conversely, consonants are composed of several parts, initially, an on-set burst known as a transient, which is subsequently followed by a rapid change in spectral content. Typically, this transition between the adjacent phonemes also occurs at a lower amplitude level. It is the combination of these factors which render consonants more difficult to discern when there is other competing noise (Cunningham et al 2001; White-Swoch & Evans et al 2015).

2.5 Implications of processing inconsistencies

Considerable scientific effort has been expended in the search for links between verbal and written language skills and reading. The role of noise and sensory processing has yielded an array of links to the struggles involving language-based learning (Cunningham et al, 2001; Sperling et al, 2005; Ziegler et al, 2005). It seems that noise may disrupt a specific acoustic cue such as a phoneme, which subsequently causes misrepresentation, and inconsistency in the events which follow it like words or sentences (Lubin, 2006). These coding deficits appear to be highly idiosyncratic, and reflective of each individual's unique auditory-cognitive system; thought to be a function of various neural generators across the *"sensory, limbic and cognitive circuits"* (White-Swoch & Evans et al 2015). When a cohort of normal three-five year olds was tested with consonant-vowel syllables, against a background of noise their auditory neurophysiological responses were slower, smaller, and unstable. This lead researchers to conclude noise impinged on the children's ability to code speech as effectively as they could in quieter situations (White-Swoch & Evans et al 2015).

It is thought by some experts in the field that poor processing in noise may be a significant contributor to general language delays and later difficulties with reading (Sperling et al,2005). Poor readers often have a cluster of auditory, linguistic, and attention deficits, including abnormal neural representation of speech and erratic performance on tasks which are psychoacoustic in nature. As yet there is no universal agreement regarding the specific sites of neural imprecision along the auditory-cognitive pathways. Some studies have shown young children had difficulties recognising consonants in speech in background noise which manifested as disruptions in the individual brains at three points including the midbrain, thalamus and the cortex (Cunningham, 2002). Other investigators suspect the temporal processing deficits commence even earlier in the brainstem responses (Johnson 2007). In 2011, Billett & Bellis recorded electrophysiological responses in children with problems around language learning; thirty percent had atypical temporal brainstem responses.

Recently a cluster of researchers at Illinois University have developed a promising thirty-minute neurophysiologic test which claims to predict future reading and literacy skills based on pre-reading abilities to accurately encode speech in noise (White-Schwoch et al 2015) The hope is that these biomarkers will provide early identification of children at risk for literacy difficulties.

Other investigations have been undertaken to assess the role auditory selective attention might play in children's ability to hear in environments punctuated by unpredictable noise. In conditions where the background noise is stable and predictable, youngsters are usually as capable as adults at identifying a sound stimulus (Jones, Moore & Amitay, 2015). However, children's hearing ability decreases substantially when noise of an unpredictable nature occurs. In one study children between the ages of four and eleven years (187 in total) were compared to fifteen adults on a 'tone in noise detection task' (Jones, Moore & Amitay, 2015). For every presentation, the masking noise was randomised. These researchers assessed the level of selective attention by estimating the level at which each listener was affected by the spectral region of the stimulus. The extent to which levels of bias, or internal noise might have contributed were controlled for using psychometric analyses. As the age of the children increased, so too did the apparent level of masking, which reached an adult-like status between nine and eleven years of age. Younger children had far greater trouble extracting information when the distracting information lay within one octave above or below the target frequency. When the frequency of the noise was more differentiated from the target signal, any age-related variation disappeared (Jones, Moore & Amitay, 2015). These researchers had controlled for other potential explanations such as: internal bodily noises (stochastic effects), bias, or peripheral hearing disorders. Thus, in this task they attributed the improvements in performance solely to selective attention. They did however acknowledge the impact of verbal skills, SES, and age in the masking variability between individuals.

2.6 Hearing impaired children

In 1999 in America, the board charged with creating guidelines for accessibility under the Disabilities act commenced proceedings about classroom acoustics, emphasizing that "*A noisy and reverberant classroom is as much a barrier to children with hearing loss as stairs are to those who use wheelchairs"* (Anderson, 2004)

Research has shown that even minimal or fluctuating hearing loss can have elusive negative effects on young students (Goldberg & Richburg, 2004). Studies suggest that the assumption of good hearing far outweighs the reality for a substantial cohort of students. Estimates of a slight degree of permanent hearing loss, or a fluctuating condition range from 30-43% for elementary students (Flexer, 1992). Others postulate that intermittent hearing loss may affects about 80% of young children under seven years old, meaning that about 60% of children will spend a third of their time unable to hear within normal thresholds (Capewell, 2014) This represents a substantial number of students whose ability to listen and learn is already compromised. Poor acoustics would have the effect of compounding their difficulties.

2.61 Inclusive Education

In North America, it is thought that sixty to eighty percent of school children with hearing loss are being educated in inclusive educational settings (Eriks-Brophy, 2013). Inclusion can be defined as the action or state of including or of being included within a group or structure (Furlonger, Sharma, Moore & Smyth-King, 2011). Here in Aotearoa/New Zealand, the MoE has a policy of mainstreaming children with hearing loss whenever this is feasible. Valentine suggests that upwards of ninety per cent of youngsters with a sensorineural loss which is permanent are educated alongside their normal-hearing peers (Valentine et al., 2002). With hearing losses varying from mild through to profound, they require support to optimize their residual hearing and mitigate the secondary effects of hearing loss, such as communication difficulties, and academic delays (Bracket, 1997) In addition to these identified cases of hearing loss, it is speculated that many other children may have an unidentified minimal hearing Impairment which has somewhat more than minimal implications (Goldberg & Richburg, 2004). For all of these students, irrespective of the exact nature of their hearing loss (sensorineural, conductive or mixed) they require optimal acoustic environments to ensure they can hear the teacher clearly, and thus have equal opportunity to maximise both their academic and social potential (Anderson, 2004; Bracket, 1997).

There is a fairly substantial body of research which has shown that these individuals may be somewhat marginalized, or socially isolated in the classroom environment (Antia, et al, 2011; Eriks-Brophy, 2013). Children with hearing loss who have been mainstreamed, have been identified as having a heightened risk of experiencing lower self-esteem, interpersonal problems, along with social rejection and loneliness when compared to typically developing children (Antia, et al, 2011; Eriks-Brophy, 2013).

In the past, predictors of success for students with hearing loss in the mainstream environment have tended to focus on variables such as early identification and well-fitting hearing aids, good speech intelligibility, along with a plethora of personality traits (Brackett, 1997; Eriks-Brophy, 2013). In the current educational climate, and with a view to social justice, alternative explanations prevail. These focus on social and environmental obstacles to the academic achievement of students with special needs—including hearing loss. Increasing, it is a lack of these inclusive environments which are undergoing scrutiny. A large part of this attitudinal shift can be attributed to the (World Health Organisation, 2001) remit, known as the International Classification of Functioning, Disability, and Health. The contemporary focus is now on physical and social environments that might impede or facilitate an individual's successful participation in everyday life. The education system is viewed as having a significant part to play in enabling these goals (Gal et al., 2010; Eriks-Brophy, 2013; Sharma & Purdy 2014, van Reenen & Karusseit, 2017)

2.62 Negative Consequences of unmitigated hearing/APD/ Language impairment

An emerging area of academic and audiological interest concerns the previously undocumented hearing, listening, and auditory processing status of youth offenders. There is a small, but growing body of research showing that language skills are often significantly worse amongst young criminals, compared to their non-offending peers (Bryan, 2004; Bryan, Freer & Furlong, 2007; Lount, Purdy & Hand., 2017; Snow & Powell., 2008). It is noteworthy, that majority of studies that have evaluated the language abilities of young people who offend have not actually considered their hearing or listening status. Despite the fact, that this population has several factors putting them at risk of developing language/hearing difficulties (Clegg, 2006; Cross, 2011). Some of these factors include poor general health, low socio economic status, chaotic, dysfunctional home environments, coupled with learning or behavioural issues (Clegg, 2006; Cross, 2011; Snow & Powell., 2011). While these studies are somewhat scarce, they do represent a new avenue of research, and one in which the findings are fairly unanimous.

In the northern hemisphere, British investigators found rates of language impairment from sixty to ninety percent, in relation to non-offenders whose rates were between three and twelve percent (Bryan, 2004; Bryan, Freer & Furlong, 2007). Their counterparts in America reported similar findings, with one paper asserting that thirty eight percent of the young delinquents in its investigation exhibited language impairments (Davis, Sanger & Morris-Friche., 1991). Results are consistent in the southern hemisphere, where, Australian researchers found that in a sample of fifty young male offenders, at least half demonstrated deficits involving narrative skill, language skills, and sentence repetition (Snow & Powell, 2008). Similar statistics occurred in Aotearoa/New Zealand where sixty percent of the young male's offenders were classified as language impaired compared with the controls group where only ten percent could be classified this way (Lount, Purdy & Hand, 2017). Poor language performance was not the only characteristic of this cohort, they also exhibited poor hearing. A total of twenty seven percent met criteria for auditory processing disorder, versus eighteen percent in the control group (Lount, Purdy & Hand, 2017).

Hearing impairment is known to be high in adults who are incarcerated in both the northern and southern hemispheres. Rates have been reported to be - thirty-forty percent - USA (Jacobson & Crowe, 1989); or seventy percent – NZ (Bowers, unpublished study 1986). Indigenous populations in both Australia and Aotearoa/New Zealand are reported to have higher rates again. These heightened rates of hearing impairment in adult Maori prisoners are in-line with Maori experiencing higher rates of all health risks than other ethnic groups in New Zealand. These needs are often unmet by the current health system (Ministry of Health, 2013). Likewise, Maori youngsters have been identified as having increased rates of hearing loss compared to their non-Maori peers (Digby, Purdy, Kelly, Welch, & Thorne, 2014). In addition, Maori children from rural areas were noted to experience some of the highest incidences of OM worldwide (Giles & Asher, 1991). The NZ research was consistent with that from other countries as it highlighted the connection between deprivation and increased rates of OM and its corollaries (Milne & Vander Hoorn, 2010).

2.63 Teaching children with hearing loss

The pre-cursor to supporting children with hearing loss through their education, lies firstly, in understanding the nature of their impairment (Marschark et al., 2011). The reduction in both the quantity and quality of sound reaching a child's brain has the potential to inhibit the development of neural connections associated with speech and language development and subsequently reading skills (Flexer, 2004). Irrespective of the degree of hearing impairment, children who are mainstreamed continue to reflect difficulty in accessing the speech of the teacher and their classmates throughout their education. Factors such as the visibility of the speaker, the general listening environment, and access to amplification systems impact on how much of the speech signal is accessible to the child (Bracket, 1997). Hearing impairment frequently degrades both the fidelity and the intensity of the original signal, which usually results in distortion and smearing of the smallest units of the speech signal, the phonemes. Consequently, these young learners frequently have the phonics of speech erroneously coded into their memories (Flexer, 2004). One unfortunate repercussion of these coding misrepresentations is the potentially incorrect categorisation of the child as having learning or developmental delays (Wright & Zecker, 2004). Additionally, a hearing loss may mean that a child appears off task, or has behavioural issues (Brackett, 1997). Increased understanding and education of teachers about the nature and impacts of hearing loss, have proven to mitigate some of these misconceptions (Marschark, 2013; Eriks-Brophy, 2013).

2.7 Types of Hearing loss

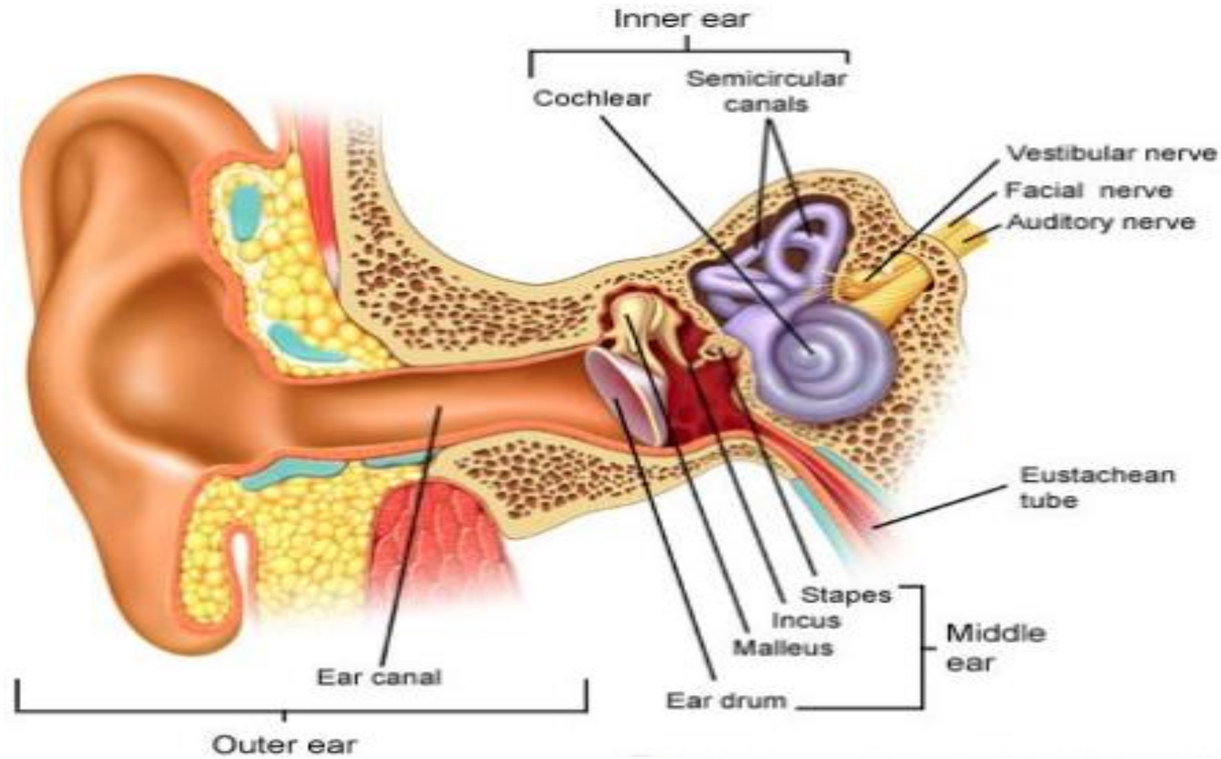


Figure 2: Anatomical features of the outer, middle and inner ear.

image retrieved from virtualmedicalcentre.com

Hearing loss can vary significantly between individuals; thus, it is important that educators have a rudimentary understanding of the aetiology of these losses, and the likely impact each type will have on a child's ability to learn successfully. The following paragraphs are intended to provide rudimentary explanations regarding some common paediatric hearing impairments. Many of which will be explored in more detail later in this document.

There are three main classifications of loss; conductive, sensorineural, or mixed, these divisions essentially identify which parts of the hearing system are affected. Firstly, a conductive hearing loss, which is caused when there is a reduction in transmission of sound from the outer ear as it moves through the middle ear. It is the most common type of auditory problem pertaining to the paediatric population, and it is often a temporary, fluctuating affliction (Hartley & Moore, 2003). The second type of hearing impairment is called a sensory-neural loss, which is located in the inner ear and may or may not involve the neural pathways up through the brainstem and beyond (Tharpe & Seewald, 2017). This type of loss tends to be permanent in nature (Stach & Ramachandran, 2014). Thirdly, a combination of these two losses which is termed a mixed loss (Stach & Ramachandran, 2014). Another two neural disorders occur beyond the cochlea, hence they are termed 'retro cochlear'. The first of these disorders tend to be physical growths or lesions involving the nervous system which cause functional hearing disorders. The second class are termed processing disorders, which include APD (auditory processing disorder) and ANSD (auditory neuropathy spectrum disorder). These conditions interrupt the normal transmission of information along the auditory neural pathways including to various parts of the brain which also process sound, not just the central auditory cortex (Stach & Ramachandran, 2014; Tharpe & Seewald, 2017). Both APD and ANSD, are frequently associated with developmental disorders.

2.71 Sensory Hearing Loss

A sensory hearing impairment is characterised by deficits in the functioning of the outer hair cells which are functioning inadequately, this is often coupled with faulty transmission of these signals to the inner hair cells within the cochlea and subsequently to the auditory nerve (Stach & Ramachandran, 2014). The reduced response to the travelling wave within the cochlea equates to a decrement in the amplification systems within the cochlea. The resulting reduction in hearing sensitivity tends to be permanent, and can range from mild to profound (Stach & Ramachandran, 2014). The aetiology of this type of hearing loss tends to be viral, bacterial, genetic or environmental in origin (Stach & Ramachandran, 2014). Hearing aids, or a cochlea implant are frequent remedial approaches to this form of hearing impairment. In a classroom setting, a youngster with a sensory-neural loss will be greatly impacted by the levels of ambient and background noise. These factors impact on the child's ability to both the perception and comprehension of speech (Anderson, 2001; Boothroyd, 2004; Crandell & Smaldino, 2000; Madell & Flexer, 2014).

2.72 Neural Hearing Impairment

This type of hearing loss is characterised by a normally functioning outer and middle ear. The site of lesion typically occurs between the cochlea and the auditory nerve, and may involve functional outer hair cells, but dysfunctional inner hair cells. It frequently includes atypical transmission of sound along the auditory nerve itself (Maddel & Flexer, 2014). The dysfunction can manifest at several points along the auditory nerve, including, the peripheral end, or further along the ascending pathway at the brainstem, or more centrally in the cortex of the brain. Alternatively, faults can occur along the entire length of the auditory pathway, or any combination of the above (Maddel & Flexer, 2014). It is characterised by disordered, asynchronous neural transmission of sound information. It is frequently atypical and unique in its presentation. This gives rise to the term by which this disorder is also known – Auditory Neuropathy Spectrum Disorder (Maddel & Flexer, 2014). The exact origin of auditory neuropathy remains unknown, although, it is thought to be associated caused with premature birth, low birth weight, oxygen deprivation, viruses, seizures, genetic anomalies among other possibilities (Maddel & Flexer, 2014).

Children diagnosed with this condition, frequently experience difficulty extracting sound such as speech from complex listening environments such as those which have high levels of background noise. Additionally, they have issues locating the exact origin of the sound source, i.e. localising. Consequently, these difficulties can be mistaken for a lack of focus or ease of distraction in a classroom setting (Stach & Ramachandran, 2014).

Auditory processing disorder (APD) is a related neural condition which typically presents with “hearing and listening difficulties, in the absence of a hearing loss” (Allen, 2016). No universal definition has been accepted, neither has a diagnosis protocol. It is mentioned at this point as the difficulties associated with ANSD are similar in APD. Enormous difficulty extracting meaning from auditory material, especially speech in environments where background noise levels are high (Allen, 2016). From a learning perspective, they will typically demonstrate a poor ability to follow multiple oral instructions, or extract meaning from spoken information. This combination of issues can result in poor academic outcomes and communication difficulties (Allen, 2016). While the peripheral hearing mechanism may be intact, difficulties occur in the transmission pathway between the cochlea and the central auditory cortex. Again, the locus of the processing difficulties is highly individualised. From a teaching perspective, children with APD require assistance utilising metacognitive strategies that increase their learning and hearing abilities (Allen, 2016). Additional benefit can often be derived from from amplification and the use of Remote Microphones at school as these increase the signal to noise ratio (Flexer, 1992).

2.73 Conductive Hearing Impairment

Clinically the likely presence of OM is diagnosed using tympanometry, and otoscopy (Schilder et al, 2016) Fluid remains in the middle ear either as a direct reaction to the infection, or it is trapped there due to an immature Eustachian tube which normally acts as a drainage channel for the middle ear cavity (Winskel, 2006). Management of OM usually involves ‘watchful waiting’ as many cases will resolve spontaneously (within 4 weeks) sans any complications, others however, will require the assistance of antibiotics or corticosteroids (Schilder et al, 2016). In chronic cases, exceeding a period of 3 months, medical intervention may be required, to drain the fluid and relieve pressure in the middle ear, typically this involves the insertion of ventilation tubes through the tympanic membrane into the middle ear space (Bluestone & Klein, 2001).

The persistence of fluid in the middle ear cavity reduces the ease of ‘conduction’ of sound waves into the inner ear which subsequently results in losses which range from a mild to moderate level, i.e. varying between fifteen and forty decibels, contingent upon the viscosity of the fluid. A thick viscous fluid causes greater loss as it restricts the normal functioning of the middle ear systems more than a thin serous fluid (Bluestone & Klein, 2001). The loss associated with OME can be transient, or it may cause ongoing life-long hearing and communication difficulties. For some individuals, the consequences of OME may require medical management later in life (Schilder et al, 2016).

2.8 Neural consequences of OME

Long term conductive hearing loss in animals has been shown to alter the anatomy and physiology of the central auditory system. This type of auditory deprivation is known to be developmentally sensitive, that is, there are known critical growth periods which are extremely sensitive to deprivation (Buran et al., 2014; Polley et al., 2013). In relation to conductive hearing loss, researchers have posited that the developing system may be vulnerable to a lack of stimulation at specific times which coincide with synapse formation and elimination in the auditory cortex (Kral & Sharma, 2013).

This may provide some evidence that perhaps, peripheral hearing loss might degrade speech input, leading to aberrant neural representation of the auditory coding of language. Specifically, the size of neural dendrites in the medial superior oliveocochlea (MSO)* bundle that are innervated by axons deriving from each ear have been shown to change following a unilateral conductive loss (Smith, Gray & Rubel, 1983). *[the MSO is located in the brainstem at the point where parallel pathways emerge, and binaural processing commences.] Other research has revealed that the balance of inputs to higher levels of the brain can also be changed by unilateral ear plugging. (Moore et al 1989). It has also been shown that unilateral earplugs can change the spatial selectivity of neurons in the auditory midbrain (King et al, 2000; Keuroghlian & Knudsen 2007). A further study in which the ferrets were raised with bilateral ear plugs showed they exhibited the greatest difficulty when background noise masked the desired signal. Interestingly, between six and twenty-four months following the removal of the earplugs and with training these animals had all regained normal temporal resolution i.e.: timing synchronicity between the ears (Moore et al, 1999)

Conductive hearing loss has been shown to affect brain function in both animal studies and from psychoacoustic evaluation of children with a known history of OME. These investigations demonstrate that the brain responds dynamically to the level of neural input it receives from the ears. In excess of thirty studies have implicated a history of OME with later APD or language learning difficulties (Downs, 1985). In one report children with recurrent OME were found to have very poor abilities to detect sounds in noisy environments, however, seven years later evidence of binaural hearing recovery had occurred (Moore et al, 2003). Many of these studies are pointing to the concept of brain plasticity. That is the capability of the brain to alter its functional organisation as a consequence of experience or deprivation.

Irvine defines it thus:

> *"Neural plasticity can be broadly defined as dynamic changes in the structural and functional characteristics of neurons that occur in response to changes in the nature or significance of their input"* (Irvine, 2007).

2.81 Possible Implications regarding OME and Auditory Processing Disorder (APD)

A longitudinal investigation in the UK conducted tympanometry on a monthly basis to ascertain the prevalence and severity of OME in children from their first year of life up until the age of six years. Three groups of risks were discernible from the results, low, medium and high. Those in the low category had minimal or no episodes of OME, while those in the middle had several bouts of various configurations and durations. Notably the youngsters in the high prevalence group frequently had bilateral OME, or at least one ear which was affected for the greater part of the first 6 years of their life (Midgely, Dewey et al, 2000). Results led the researchers to conclude that individuals in this high incidence category are at greater risk of educational difficulties due to the neural consequences associated with OME. Some have proposed that even a brief hearing loss disrupts binaural integration during two early critical periods of cortex development (Polley, Thompson & Guo., 2013). Conductive losses such as those produced by OME have been implicated in reduced higher order cognitive levels of auditory integration, especially speech recognition, auditory memory & binaural processing (Gravel, Wallace, & Ruben 1995).

It is thought that hearing comprehension is the result of two process which have been labelled "top-down", and "bottom-up" processes (Moore, 2012) Where top-down processes involve the interactions between sensory and higher-order cognitive/linguistic operations.

(Amitay, Zhang et al, 2014, Moore, 2012) The other half of this equation is the bottom-up processing which is a consequence of several factors in the peripheral auditory system, including; the underlying anatomy, and physiological function (Moore, 2012). Also, information processing which involves feature extraction in multiple, parallel pathways, and subsequent reintegration and synthesis of this information (Bamiou., Musiek., & Luxon, 2001).

Use of the acronym APD initially occurred during the 1950's, when a variety of clinicians (Mykelbust/Berry & Eisenson/ Boccca & Calearo) noted a 'central' aspect to some children's inability to hear well. Both scientific and clinical research into the subject of auditory processing disorders (APD) has increased and advanced since then, but particularly in the last ten years. More is known about the condition, how to assess it, and select appropriate interventions. The term APD was selected as it allows for dual recognition of the peripheral and central aspects of hearing (Bamiou., Musiek., & Luxon, 2001). However, one of several difficulties associated with APD is the tendency for it to be co-morbid with other conditions, such as Dyslexia, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum, Auditory Neuropathy/ Dysynchrony (Cacace & McFarland, 2006; Miller & Wagstaff., 2011; Rosen S.; 2003; Sharma et al, 2009). Hence, comorbidity of these conditions is well documented even though causal links have not yet been established. There does not appear to be sufficient evidence to conclude that reading, language and attention disorders are due to dysfunction in a single perceptual modality, i.e. they may be multi-modal (Cacace & McFarland, 2006).

Increasingly the lines of biological evidence are converging to indicate that children who struggle to read frequently have deficient neural encoding of sound as evidenced by their inability to synchronise to a beat (Carr et al, 2014; Helm & Friedman et al, 2011; Hornickel & Kraus, 2013; Tierney & Krause, 2013). Some have termed this an auditory motor deficit (Carr et al, 2014). It is mooted that sensitivity to temporal modulations in speech affects the neural processing of the units of speech resulting in a breakdown of the temporal encoding of speech segments which could impede the development of phonological skills critical for language learning (Carr et al, 2014; Hornickel, Skoe et al, 2009). Some authors posit that poor beat synchronisation coupled with poor neural auditory processing might be an early indicator for youngsters at risk of language-learning problems (Corriveau & Goswami, 2009). If so, steps to remediate these difficulties could be instituted early, i.e., prior to a diagnosis of reading delay. Musical training has been suggested as a possible therapeutic approach for those exhibiting pre/reading troubles (Tierney & Krause, 2013). *"In tune, but out of time"* is how some investigators have referred to the dyslexic brain (Corriveau & Goswami, 2009).

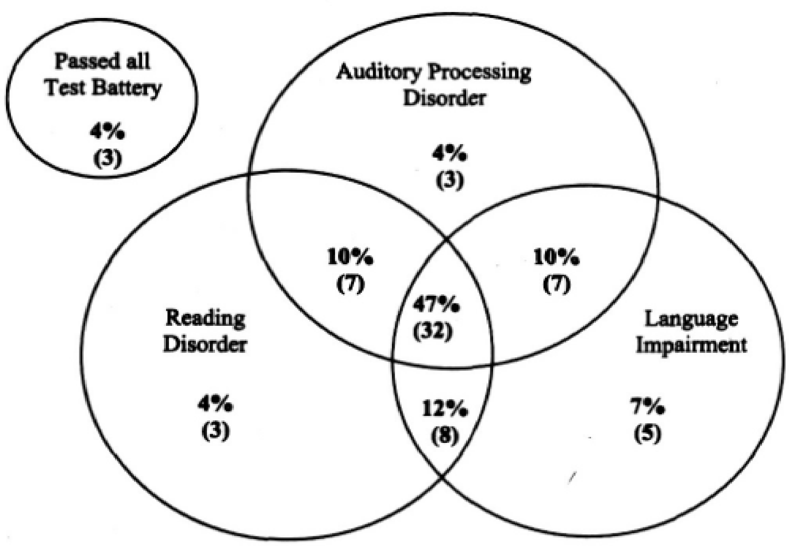


Figure 3: Diagram showing the overlap between some learning difficulties. (Sharma et al, 2009)

2.9 Lack of International Consensus for Definition of APD

As yet, there is still no international agreement on a definition of what constitutes APD which adds considerably to the difficulty of selecting strategies for assessment, diagnosis and intervention. Another confounding aspect of APD is that its manifestation within individuals is highly idiosyncratic. The American Speech Hearing Association has attempted a number of formal definitions, (1996, 2005) the current statement reads: *(Central) auditory processing disorder [(C)APD] refers to difficulties in the processing of auditory information in the central nervous system (CNS) as demonstrated by poor performance in one or more of the following skills: Sound localisation and lateralisation; Auditory discrimination; Auditory pattern recognition; Temporal aspects of audition including; Temporal integration, Temporal discrimination, (e.g. temporal gap detection), Temporal ordering, and Temporal masking; Auditory performance in competing acoustic signals (including dichotic listening); and Auditory performance with degraded acoustic signals*.

In 2011, the British Society of Audiology (BSA) revealed its approach to APD by issuing the following position statement: APD is characterised by poor perception of both speech and non-speech sounds. It has its origins in impaired neural function. APD impacts on everyday life primarily through a reduced ability to listen, and so respond appropriately to sounds. APD should be assessed through standardised tests of auditory perception. APD does not result from failure to understand simple instructions. APD is a collection of symptoms that usually co-occur with other neurodevelopmental disorders (BSA APD –special interest group, (2011).

Given that the establishment of a definition, let alone a gold standard of assessment seems a long way off some researchers have opted instead to re-direct their focus towards the diagnosis and management of listening difficulties. In 2015, the National Acoustics Laboratory (NAL) in Australia issued a position statement which reads: *An Auditory Processing Disorder (APD) is a deficit in the way the neural representation of sounds are processed by the brain, resulting in a distorted neural representation of the auditory signal within the auditory nervous* *system*. In other words, APD creates difficulty in listening (i.e. hearing with intent to extract information). (Dillon et al, 2012) By-passing the semantic nosology argument surrounding definitions of APD has enabled investigators at NAL to re-prioritise their research endeavours towards the management of presenting difficulties, specifically, the development of outcomes-based programmes to assist children exhibiting listening difficulties, for example, the Listening in Spatialized Noise—Sentences test (LiSN-S). The creation of models of APD, which view the term as an umbrella description for a pattern of findings that frequently appear together, whilst simultaneously acknowledging the heterogeneous nature of APD will be vitally important in refining our understanding of auditory processing mechanisms (Dillon et al, 2012).

The existing literature has not diagnosed the 'true' nature of auditory processing difficulties and many questions remain unanswered. It could be that; auditory processing disorders may be a characteristic feature of both developmental and neurologic conditions. At this point in time, in the literature, APD appears to be validated in relation to certain syndromes, however, in relation to other disorders the calibre of evidence seems inconclusive and the connection between APD and a coexisting disorder is minimal at best. It is clear that considerable research is still required into the nexus between APD and various neurological and developmental disorders. The ability to better explain the nature of auditory processing deficits is likely to have implications for suitable management, in agreement with the progression toward multimodal intervention for these disorders (Bamiou., Musiek., & Luxon, 2001).

Researchers estimates of the prevalence of APD in school children range from seven percent (Bamiou, Musiek, & Luxon 2001) to between two and five percent (NAL, 2015) others suggest three to five percent at a ratio of 2:1 boys to girls (Chermak & Musiek, 1997). In the context of Aotearoa New Zealand the presence of APD in 6-14 year olds is estimated to be around 6.2 %.Demographically, 35.5% are Pacific Islanders, 5% are Maori, 2% other ethnicities (Wright & Esplin, 2014).

2.91 Education and otitis media

Recurrent, or chronic episodes of OME have been linked to developmental delays and learning difficulties, in part this is due to the timing of the episodes which typically occur during the first three years of life when the acquisition of speech and language is commencing (Winskel, 2006). A study conducted in Australia which tested children aged six and eight years for phonological awareness, reading ability and knowledge of semantics the researchers found differences between those who had a history of otitis media, and those who didn't. There was a noticeable trend for the youngsters with a history of OM to have "*reduced scores on phonological awareness skills of alliteration, rhyme and non-word reading, plus, semantic skills of expressive vocabulary and word definitions and reading than non-OM children*." (Winskel, 2006). These findings align closely with a 2005 investigation into children who had a mild fluctuating conductive hearing loss, up until the age of five as a consequence of a history of chronic OM or frequent infections of the middle ear. Youngsters in this cohort also demonstrated heightened probabilities of delayed reading skills compared to their contemporaries with healthy middle ears (Golz, Netzer, Westerman et al, 2005; Silva, Chalmers & Stewart., 1986). Historically, Aotearoa/New Zealand had literacy rates which were high by international standards (Guthrie, 1981). For a number of years now, these rates have declined noticeably, and are lowest among Maori children, and those of Pacific Island origin (Marriot & Sim, 2014)

The literature however, remains engulfed in debate, there are a number of studies which do not appear to substantiate the hypothesized link between OME and the associated hearing loss with delays in language development. One such study of forty-four children found no significant relationship between childhood OM and performance on tests of verbal intelligence or academic achievement after three years of schooling. Although they did note that the number of days of OM prior to three years of age was significantly correlated with teachers' ratings of children's attentional behaviour in the classroom. In addition, these children were also rated as less task oriented and less able to work independently than children with less otitis media. The behavioural aspects related to OM is yet another avenue worthy of more investigation (Roberts, Burchinal, Collier, et al (1989).

A meta-analysis which examined the findings of over 100 studies conducted during the preceding thirty-year period found a mixture of results, both for and against a linkage between OM and later language difficulties (Roberts, Rosenfeld, & Zeisel, 2004). One of the problems with the research was the number of different methodological approaches used. This meant many of the papers were unable to be compared, due to confounding variables such as the childcare situation, mother's education, social economic factors, that have been shown to impact significantly on children's language capabilities. In all, only four of the eleven analyses turned up a minor significant association. This led the researchers to conclude that studies needed to be considerably larger, and preferably longitudinal, if they were to have sufficient statistical power to prove the hypothesis that a history of OM is likely to interfere with language processing by; *"causing a child to encode information inefficiently, incompletely, or inaccurately into the database from which language arises."* (Roberts, Rosenfeld, & Zeisel, 2004).

Whilst there are many issues which remain unresolved, or inconclusive in the literature, one recommendation which appears to be universal is the need for all children with language, learning and listening problems is that they require suitable listening environments, including the reduction in background noise.

2.92 NZ Education & the current status of Auditory Processing Disorder

Currently, in Aotearoa/NZ, there seems to be widespread deficiencies of identification and comprehension of auditory processing disorder (Wright & Esplin, 2014). This lack of recognition exists within a number of sectors in society including education, health, families, and wider community. Approximately five per cent of the general population in the demographic aged between six and fourteen years are thought to be affected by APD (Wright & Esplin – Statistics NZ 2013). However, recent studies suggest that the prevalence could be as high as thirty-six per cent amongst the Pacific Island paediatric population. This represents a rate which is six times greater than the general population (Wright & Esplin – Statistics NZ 2013). There is also some suspicion that APD may be more widespread than these statistics suggest, as there is both a paucity of qualified diagnosticians, and therefore, an inconsistent and inadequate service provision throughout the country (Wright & Esplin, 2014).

Perhaps one of the most important considerations is that APD is not formally diagnosed until the age of seven at the earliest, as there are effects related to both age and linguistic ability prior to this age. This is also confounded by the heterogeneity associated with APD. As a consequence of these delays in confirming a diagnosis of APD it is possible for a child to be attempting to learn in a noisy classroom environment for a substantial period without any technical assistance from an FM system. This had led some parents to the conclusion that home-schooling their child is a more suitable option... Such responses raise questions around the implementation of the World Health Organisation's ICF (International Classification of

Functioning disability and health) framework around the management of APD in school aged children in the NZ education system (Sharma & Purdy, 2014; Wright & Esplin, 2014). Anecdotal evidence from specialists, such as teachers, SLT, audiologists, familiar with the child is that while they may suspect APD, they are effectively constrained and unable to even trial an FM system to assess its potential efficacy, unless the child's parents self-fund the equipment (Wright & Esplin, 2014). While a causal relationship has yet to be established, several co-morbid conditions have been identified, including potential difficulties around reading, attention, and behaviour (Gyldenkærne, Dillon, Sharma, & Purdy, 2014) Sharma et al, 2009).

The use of a personal FM system, may be the most significant "bottom-up" intervention, but this does not preclude a multi-faceted approach including "top-down" processes. It is postulated that the augmented auditory signal delivered by the personal FM system may be able to hasten or boost the impact of auditory training in children with APD (Smart, Purdy, Kelly, 2018). Studies suggests that 'attention' is strongly associated with auditory perceptual learning (Amitay, Zhang, et al, 2014; Halliday, Moore, et al, 2011; Moore & Amitay, 2006). Additional research is warranted in around this possibility. Supplementary strategies may also include, counselling for parents and teachers around listening and communication strategies for the child. Priority seating and using speech cues can also be helpful. Complimentary courses and therapeutic approaches may also be advantageous (Sharma, et al, 2012). The literature is equivocal in regard to online courses, or computer-based training programmes (Wright & Esplin, 2014).

There is substantial, and mounting evidence that children affected by APD are likely to derive substantial benefit from FM devices which assist them to hear better particularly in noise. Increasingly, studies indicate that the use of assistive technology like FM systems are efficacious, as they drive neural plasticity in children (Frederichs, & Frederichs, 2005; Hornickel, et al, 2012, Umat, et al, 2011). These findings are predicated on the understanding that neuroplasticity and neuro-maturation are dependent on stimulation. Analytical studies of brain development demonstrate that sensory input not only stimulates the auditory centers of the brain but is critically implicated in the actual configuration of auditory cortical pathways (Flexer, 1999). Investigations which have focused on raising the levels of auditory stimulation have yielded measureable changes in the morphological configuration of the auditory parts of the brain (Kitzes, Farley & Starr, 1978; Ryugo & Weinberger, 1978).

Consistent use of a personal FM system therefore, seems likely to provides the maximum achievable benefit, especially in noisy environments such as classrooms. Hearing aids alone, are considered insufficient, in a classroom situation as they are unable to provide the necessary increase in the SNR of the teacher's speech unless they are paired with a personal FM system (Hoen et al, 2010; Johnson, et al, 2004; Keith & Purdy, 2014; Kuk, et al, 2008, Kuk, 2011; Smart, et al, 2008; Yip & Rickard, 2011).

The most recent evidence published in 2018 in support of this approach to the management of APD comes from authors Smart, Purdy and Kelly who gathered evidence of an electrophysiological nature from children with APD in the form of cortical auditory evoked potentials (CAEP). The trial involved twenty-eight children aged between 7-12 years who were fitted bilaterally with an FM system which they wore during their normal school classes for a period of two terms. The recordings showed that noise resulted in increased P1 and N2 latencies, and reduced N2 amplitudes for this cohort. Significantly, these responses were demonstrably reduced when the participants were fitted with an FM system. The efficacy of this approach was evidenced in the thirteen per cent average improvement for speech in spatial noise scores.

Furthermore, seventy four percent of teachers rated the trial as successful given their responses to LIFE-UK ratings. Likewise, questionnaires administered to the children's parents also produced similarly good agreement with those from the educators. Another noteworthy outcome was the substantial improvement in the behavioural measures of auditory processing which was reinforced by the participants own evaluations of their ability to listen with the FM system (Smart, Purdy, Kelly, 2018)

In NZ, the current funding models for assistance for APD are divided between the Ministry of Health, and the Ministry of Education. Where the former essentially conducts the diagnostic process: often in conjunction with professionals in private or academic clinics as not all district health boards (DHB) provide APD assessment. Subsequently, the MoE assumes responsibility for the provision of HA, and FM systems. There has been some level of dissatisfaction with this approach from stakeholders including parents, teachers, audiologists (Wright & Esplin, 2014). Some of the difficulties regarding access to funding stem from the lack of agreement around diagnosis and treatment (Wright & Esplin, 2014). Further inequities are apparent as a consequence of geography which may limit the availability of diagnostic services. Discrepancies around access also arise as a function of a family's socio-economic-status which may mean some families are unable to afford to pay privately for assessment or treatment of APD (Wright & Esplin, 2014).

At the present time, the MoE requires a definitive diagnosis of APD prior to a child receiving consideration for an FM system. Due to a lack of clarity around what constitutes APD, the considerable heterogeneity between cases, and which array of tests ought to be used, it may not be possible for a diagnosis to reach the "definitive" criteria required by the MoE (Wright & Esplin, 2014). Irrespective of recommendations from various professionals, including audiologists often, requests for FM systems, or even a trial are frequently denied. Increasingly the stakeholders seeking access to public funding for such systems are reporting the MoE system of allocation is unfair, and inequitable (Wright & Esplin, 2014). This is understandable given that the MoE does fund personal FM systems for children with other sensory hearing impairment who have learning difficulties and may derive benefit from this technology. The figures from a fourteen-month period from January 2012-April 2013 indicate that the MoE that fifty-one FM systems were allocated to children with APD, whereas more than two hundred systems were issued to pupils with a sensorineural hearing impairment (Wright & Esplin, 2014).

The present protocol which informs MoE funding decisions is whether the "primary need is for learning in the classroom" (Wright & Esplin, 2014). Some stakeholders consider this interpretation is being applied too narrowly. Additionally, individual schools may have other students which they determine have greater learning needs, and hence MoE funding may be prioritised into supporting these youngsters at the expense of a child with APD (Wright & Esplin, 2014).

2.93 Teaching & hearing loss

Ninety per cent of children with hearing loss in Aotearoa/New Zealand will be educated in classrooms with their normal hearing peers. Across the Tasman, in Australia the rates are estimated to be over eighty percent of deaf or hard of hearing youngsters learning in regular classrooms (Hyde & Power, 2004) Naturally, there are both benefits and costs to this inclusive approach which raise issues for teachers, parents, and various hearing specialists such as audiologists. For the benefit of this discussion, 'mainstreaming' and 'inclusion' are used interchangeably, although some authors differentiate between the terms (Thomazet, 2009). One of the central tenets of mainstreaming is to *"ensure that all children have a fair, equal and significant opportunity to obtain a high-quality education."* (Savich, 2008). This is a sentiment which is endorsed by this country's Ministry of Education through its policy statement, the 2016 Designing Quality Learning Spaces -Acoustics document. Conceptually, this idea of integration has social and political merit as it is linked to issues of equity, social justice, and human rights (Gal et al, 2010). Further benefits derived by the hearing-impaired child include stimulating both their academic and social development. The participative nature of mainstreaming encourages increased interaction with peers, increases self-esteem and confidence along with reductions in behavioural problems (Murawski, 2010). Parents, educators, and the pupils themselves particularly appreciate these aspects of inclusive education (Andrews & Lupart, 2000; Blecker & Boakes, 2010). As a model of education, mainstreaming is also purported to encourage equality between students and promote the evolution of a social conscience, whilst also decreasing the stigma which is often attached to learners with special needs (Eriks-Brophy, 2013)

For mainstreaming to be successful, teachers need to be able to produce an environment which is conducive and responsive to the differing needs of their young learners. Recent trends in teacher education, in some countries at least, suggest that the profession is being adequately informed about aspects of inclusive practice, concerning children with hearing loss (Eriks-Brophy, 2013). This Canadian study involved surveying sixty-three teachers who were assessed on their attitudes, knowledge and skills regarding the hearing-impaired child. Overall responses affirmed that their training and professional development courses, had provided them with some appropriate skills to enable them to teach effectively in classrooms where mainstreaming occurs. Their responses indicated that they felt well informed about the effects of hearing loss on language and learning in general.

When it comes to the provision of services to children with language, or hearing difficulties two models which are currently in vogue involve a mixture of withdrawal, and/or consultation. Where withdrawal involves the student being removed from the class and receiving separate tutoring. Or, consultation which means, the AODC, SLT, RTD, etc. visit children in an itinerant manner. Along with providing some direct support to the child, they increasingly act as consultants to the child's regular teacher, equipping them strategies to support the child within a mainstream environment (Eriks-Brophy, 2013). Teachers in the Canadian study noted that eighty four percent of their hearing-impaired pupils were supported through a withdrawal model while ten percent were engaged in a consultative model.

While the teachers felt their training courses equipped them to be knowledgeable, and efficacious in the education of hearing impaired children they did note that the support from specialist itinerant teachers was paramount to the child's success and how confident the teachers themselves felt (Eriks-Brophy, 2013). Similar sentiments were expressed in regard to the need for collaborative inter-professional practice (Fisher et al, 2003; Furlonger, Sharma, Moore, & Smyth-King, 2010). This last point seems particularly relevant to the NZ situation, given the increasing presence of MLE, and the associated increased class sizes, and subsequent noise levels a child is likely to be exposed to during lessons. One aspect of the study which was not considered in the questionnaire was the nature of the classrooms in which the teaching occurred, either traditional cellular or open modern learning environments. It would have been interesting to note whether this influenced the teacher's feelings of competency or their assessment of mainstreaming in any way. More so given that these educators did indicate a preference for smaller class sizes which they thought would be particularly beneficial for their hearing-impaired learners.

This is essential given the estimations that seventy per cent of children have had at least one episode of OM prior to reaching three years of age (Winskel, 2016). One study observed that four or more episodes of OM during this critical period appeared to produce greater difficulties in phonological awareness (Menyuk, 1986). That is the ability to 'tune into' the speech sounds which characterise language, in particular they lack the ability to 'break into' the streams of speech and allocate meaning to these parts (Menyuk, 1986; Nitrouer & Burton, 2005). It is suggested that this reduced phonological awareness, i.e. the ability to identify and manipulate certain sounds impacts negatively on later reading ability (Bryant, Maclean, et al, 1990; Menyuk, 1986; Wagner, Torgesen & Rashote, 1994). In addition, a mild fluctuating loss during childhood has been shown to interfere with both expressive and receptive language acquisition (Roberts & Wallace, 1997). It appears from some studies that the connection between verbal language skills and reading is not uniform and that it could conceivably change during the process of early reading. To begin with phonological skills are significant to enable word decoding, and subsequently, higher order processes involving semantic knowledge and narration may become more influential for fluent reading comprehension to occur by eight or nine years of age (Roth, Spence & Cooper, 2002).

Given that so many young children may have experienced some compromise in their auditory development due to their exposure to OM, it reinforces the need for good acoustics to ensure that any deficits caused by poor acoustics and high background noise impact negatively on junior learner's education. Empowering teachers with knowledge about hearing loss is vital if mainstreaming is to be successful for children with hearing difficulties. A particular emphasis should be placed on the possible implications of OME and APD on the development of language and literacy skills. Having some understanding of classroom acoustics, should be viewed as an integral facet of understanding hearing difficulties in young children. The two topics are complimentary, because teachers who are well-informed about hearing loss and empowered to manage classroom acoustics should be able to address some of the inequities and under-achievement prevalent amongst children with hearing difficulties.

Researchers have suggested that at least half of the variability in deaf or hard of hearing students' achievement may be because of teaching factors, and other investigations have indicated that when lessons are run by experienced teachers of the deaf in mixed classrooms, students with hearing difficulties may gain just as much as their hearing classmates (Marschark et al 2011). Given that the discoveries concerning language and cognitive differences between youngsters with and without hearing difficulties are fairly recent along with the variation in teaching styles between educators with and without experience in teaching children with hearing troubles. Capitalising on this evidence ought to provide a significant opportunity to redress some of the academic outcomes for children with hearing impairments (Marschark et al 2011).

3.00 The Acoustics of Classroom Environments

Appropriate classroom environments are important, considering that a large proportion of youngsters may commence their education with a somewhat compromised auditory system which has the potential to impact negatively on their speech and language development but also their attention, behaviour, and socialisation (Williams & Jacobs, 2009).

The classroom situation is largely and auditory-verbal experience, where learning takes place as a consequence of hearing well. Researchers estimate that the duration of time children spent listening to their teacher or peers range from forty-five to seventy five percent. (ASHA, 2005). It is therefore imperative that the speech signals within the classroom are clear and accurate if learning is to be optimised (Crandell & Smaldino, 2000). Several factors influence the ease with which a spoken signal is heard. The physical design of a building influences factors such as the reverberation time (RT), and the background noise levels, which in turn affect the signal-to-noise ratio (SNR) (Crandell & Smaldino, 2000; Wilson et al, 2002). The most important aspect which influences the optimal speech recognition is the difference between the intensity of the signal of interest and the intensity of the background noise at the child's ear (Crandell & Smaldino, 2000).

Several architectural and construction factors influence the behaviour of sound in classrooms. Historically, in this country, many classrooms were built to design standards outlined in the MoE Health and Safety Code of Practice for State Schools (1993, 1995), then later, the Australian and New Zealand Standard AS/NZ2107:2000 Acoustics- Recommended design sound levels and RT's for building interiors (Wilson, 2002). These papers specified that unoccupied classroom noise levels in primary school teaching spaces were suitable when they were between (35-45 dBA). Where, dBA is the "equivalent" average sound level measured by using the A-weighting most sensitive to speech intelligibility frequencies of the human ear (Clark, Martin, van Kempen et al, 2005) 'Satisfactory' is classified as thirty-five decibels (Aweighted = based on human hearing) is the level of noise that has been found to be acceptable by most people for the environment in question and also not to be intrusive. 'Maximum Design Sound Level' is reached at Forty-five decibels (Aweighted = based on human hearing) as the level of noise above which most people occupying the space start to become dissatisfied with the noise (AS/NZS:2107: 2000). This standard also specifies that the reverberation time range from 0.4-0.5 seconds where RT is the time it takes for a sound to decay sixty decibels once the original sound source has stopped. (AS/NZS:2107: 2000). When children with learning difficulties, or those for whom English is a second language, the RT ought to be no greater than 0.4 seconds. Currently, these standards are encapsulated in new MoE document entitled: Designing Quality Learning Spaces – Acoustics, 2016 which pertains specifically to teaching spaces for children rather just general building interiors. It is noteworthy that the acoustic parameters have ‘guideline’ status only; i.e., they are not mandatory.

These specifications are identical to those recommended for classrooms in the USA by the Acoustical Society of America (ASA 2000). However, the American Speech-Language-Hearing Association (ASHA) is a little more stringent in its recommendations suggesting: unoccupied classroom noise levels should not be greater than 30 dB (A), RT should not be greater than 0.4 seconds, and the signal to noise ratio (SNR) at a pupil’s ear should be greater than +15 dB (Wilson, 2002).

3.01 Significance of Background Noise Levels (BNL)

The presence of noise interferes with children’s ability to hear speech. The quieter parts of the speech signal such as consonants are particularly affected by low frequency noise which tends to mask out this information (Wilson, 2002). ‘Noise’ can be classed as unwanted sound which is deemed to be unpleasant, loud or disruptive to hearing (Moore, 2012). Noise can be described by its frequency, loudness, fluctuation, and meaning (van Reenen & Karusseit, 2017). In the typical classroom environment, it is usually sounds other than the voice of the teacher or classmates.

Noise per se can be classified as either external, or internal. In the case of the former, external noise can arise from a variety of sources, including: aeroplanes, building/ construction sites, vehicles on roads, sirens/alarms, activities in the playground, adjacent classrooms, school maintenance (lawn mowing etc.) Nelson, Soli & Seltz, 2002). Internal noise is usually derived from sources including the following: pupils themselves, teachers, heating/cooling units, lighting, projectors, computers (Nelson, Soli & Seltz, 2002). Noise levels are reported to be greatest in the classrooms of the youngest learners (Wroblewski et al, 2012). Research has demonstrated that children have perturbed auditory physiological responses to speech in the presence of background sound (Hornickel, Skoe et al, 2009; White-Swoch et al, 2015).

3.02 Significance of Reverberation Time (RT)

Reverberation time is quantified as the number of seconds it takes for the signal to reduce by 60 decibels. The volume of a room, and the materials used to line its interior surfaces are the features which impact most significantly on its RT. Hard, shiny surfaces such as concrete, and glass are highly reflective, whereas soft materials such as carpet and curtains tend to absorb rather than reflect sound (ASHA, 2005).

Where noise affects the perception of speech, RT tends to impact on its clarity. This is because the reflected signal tends to overlap with the original signal effectively ‘masking’ or ‘smearing’ it. (Anderson, 2004; Bradley, Sato, & Picard, 2003; Wilson, 2000). When there is little reverberation within an enclosed environment, the noise decays rapidly, and consequently cannot interfere with the original direct signal (Nabelek & Robinson, 1982). The counterpoint to this is, the longer the RT, the greater the impact on speech perception. This is largely a consequence of the speech signal bouncing around the room and effectively filling in the spaces between words in the original speech (Bradley, Sato, & Picard, 2003; Crandal & Smaldino, 2000). Long RT have a particularly detrimental impact on speech recognition in children who are hearing impaired. (Carr, 1995). A review of the literature indicates that suitable RT's for those with hearing loss are rarely achieved (Crandal & Smaldino, 1995; Knecht et al. 2002)

3.03 Combined Effect of BNL & RT on Speech Perception

The dual effect of background noise and reverberation time combine to have the synergistic effect of heightening the degradation of speech perception. (Bradley, 1986; Irwin & McAuley, 1987). On occasions when the background noise level rises by ten decibels, the intensity of the speech signal also has to be raised by ten decibels in order for the speech to remain equally perceptible (Bradley, 1986). However, the combination of reverberation plus noise negatively alters a person's threshold for speech due to the amount of distortion from these two acoustic features (Irwin & McAuley, 1987). The longer the RT, the greater is the degree of speech masking which occurs. This has been attributed to the effect of temporal smearing, as it occurs even when the level of background noise is remains constant (Anderson, 2004). When classroom RT levels are within the guidelines of 0.4 to 0.5 seconds, the most detrimental kind of noise is speech noise, or noise that occurs within the spectrum of speech (Nabelek & Robinson, 1982). In addition, where a room had a long RT it was the impulsive noise which had a worse effect on speech reception compared to speech babble, or a steady-state noise (Nabelek & Robinson, 1982).

The progression from childhood, through until the teenage years reveals that there is a noticeable progression of ability to discern speech in the presence of noise alone, or noise coupled with reverberation (Johnson, 2000; Wrobeleski, et al 2012). It is especially significant that when fluctuating maskers were used, such as single-talker speech (Wightman and Kistler, 2005), performances akin to those of an adult were not generally achieved in youngsters under the age of ten years. It seems children are less able to make use of spectro-temporal and spatial cues for separation of signal and noise (Hall et al., 2005).

For many years now, it has been known that the performance of complicated tasks in noise results in a deterioration of performance, unlike a simple task, where the outcome remains unaffected (Broadbent, 1958; Park & Payne, 1963) In addition, performance decreases when the type of noise is distracting in nature, irrespective of whether it is intermittent, or continuous (Broadbent, 1958). Further to this, speech-like noise degrades performance considerably more than non-linguistic noise (Slater, 1968). Interestingly, these effects occurred when speech was reversed, or non-sensical, or in a foreign tongue (Smith, 1989). Human beings, do not adapt, i.e. habituate to listening in these sub-optimal conditions (Anderson, 2004). When this knowledge is applied to children endeavouring to learn in noisy environments, particularly those whose classrooms are subject to speech transmission from adjacent rooms, with or without considerable background noise, they can be considered to be at risk for greater difficulty in processing unfamiliar or complex information delivered via oral instruction from the teacher.

3.04 Speech Transmission Index - STI

The STI is a measure of the **quality** of speech transmission. It is a classification system which enables a numeric value to be assigned to likelihood of individual aspects of speech being understood, i.e. syllables, words, and sentences. (Van Wijngaarden et al, 2012). Each of these three facets of speech are scored as a percentage of their overall intelligibility, which subsequently contributes to the final STI score which ranges from Bad, (rated as 0) to Excellent (rated as 1) (Van Wijngaarden et al, 2012). The scale is recognized internationally under the IEC standard 60268-16, edition 4, 2011, which allows the STI to be used in a variety of different environments such as rooms, phones, electronic equipment (Van Wijngaarden et al, 2012). It is a well-researched, objective measurement of the impact the environment or transmission medium has on speech intelligibility. It does not measure 'speech intelligibility' per se. (Steeneken & Houtgast, 1980). One aspect which may explain the popularity and universality of the STI is that its predictions are essentially independent of the particular language under consideration, as such it has earned the moniker "*The Common Intelligibility Scale* (Barnett & Knight, 1995). This makes it a particularly interesting factor to analyse when considering classroom acoustics, as it means the findings can be compared to other international results.

STI prediction is independent of the language spoken –refers to transmission of physical patterns common to speech universally. STI predicts the likelihood of syllables, words and sentences being accessible to listeners. It is a numeric representation which ranges in value from 0 = bad to 1 = excellent. As an example, for native speakers, this likelihood is presented in Table 1.

Table 1: Quality of Speech transmission using IEC 60268-16 standard to predict the Intelligibility of universal parts of speech including syllables, words, and sentences .

STI value	Quality according to IEC 60268-16	Intelligibility of syllables in %	Intelligibility of words in %	Intelligibility of sentences in %
0 – 0.3	Bad	0 – 34	0 – 67	0 – 89
0.3 – 0.45	Poor	34 – 48	67 – 78	89 – 92
0.45 – 0.6	Fair	48 – 67	78 – 87	92 – 95
0.6 – 0.75	Good	67 – 90	87 – 94	95 – 96
0.75 – 1	Excellent	90 – 96	94 – 96	96 – 100

IEC. (2011). Part 16: Objective rating of speech intelligibility by speech transmission index (4th edition), in IEC 60268 Sound System Equipment (Int. Electrotech. Commiss., Geneva, Switzerland:).

3.05 The Lombard effect & the Café effect

One of the consequence of combining a reverberant location with speech and background noise is that it causes individuals to raise their voice levels as they attempt to be heard by both themselves, and those with whom they are conversing. This largely subconscious vocal competition with others in the same room has been termed the Lombard effect (Lubman & Sutherland, 2002; Whitlock & Dodd, 2006). As a consequence of the Lombard effect, the overall noise intensity of the environment tends to increase, in a phenomenon which is known as the Café' effect (Lubman & Sutherland, 2002). That is, "*the tendency for noise to breed noise*" (Whitlock & Dodd, 2006). Experiments have enabled researchers to quantify this effect into a 'Lombard Coefficient', that is the amount a voice is raised by in relation to the background noise level. Children in the Whitlock & Dodd study raised their voice by approximately 14 dB(A) more than adults who spoke louder by only 11 dB(A) approximately. That is a coefficient for children of 0.19dB per decibel increment in background noise while adults equalled 0.13 dB/dB (Whitlock & Dodd, 2006). Other studies have found higher coefficients (Sutherland et al, 2005). Importantly, the acousticians in this 2008 study Whitlock & Dodd, have incorporated these coefficients into an equation with several other variables which has led to the development of a predictive model for classroom noise levels. Significantly, these levels are in agreement with the acoustical outcomes of other contemporary research into classroom acoustics (Lubman & Sutherland, 2002; Shield & Dockrell, 2003; Wilson et al, 2002) Several researchers propose that the Lombard Effect is almost entirely responsible for the subsequent activation of the café effect. (Lubman & Sutherland, 2002; Whitlock & Dodd, 2006). As a consequence of potentially being able to forecast and control the background noise levels in a particular teaching space the hope is that the café effect can be limited, if not essentially avoided. The use of simple noise level meters, such as Talk-Light, or in MLE has been suggested as an efficient and effective means for teachers and pupils to manage the Lombard/Cafe effects. The suggested parameters are 40dB(A) for quiet activities, and 60-65dB(A) for louder activities (Whitlock & Dodd, 2008)

Several studies have reported that reducing the RT appears to have a two-fold effect. Firstly, it improved speech intelligibility, and secondly, it seems to have suppressed the Café effect by helping reduce activity noise from the children (Lubman & Sutherland, 2002; Whitlock, 2003). When acoustic ceiling tiles were installed in a classroom they lowered the RT from 0.62 to 0.52 seconds the activity noise recorded over a full day was reduced by six dB when the predicted reduction was only one decibel (Whitlock, 2003). When the RT was reduced from

1.92 to 1 second in another experiment, a lowering of noise in the vicinity of 12dB occurred when only 3dB was forecast (Lubman & Sutherland, 2002).

The Essex study provides further evidence in support of optimal classroom acoustics (Canning & James, 2012). In a six month, long study three mathematics classrooms at a secondary school in the UK received modifications which would alter the acoustic performance of the room. The investigation was conducted as a blind study, so, the alterations caused no apparent visual changes to the rooms, nor were the staff or students told when the modifications occurred. A fourth room was maintained its original state as a control. Both quantitative and qualitative analysis occurred which included a combination of interviews and acoustic measurements that consistently revealed the teachers preferred the room when it had received the maximum acoustic treatments, that is, higher than the minimum legislated building requirements for school rooms, (RT below 0.8 seconds from 500Hz-2K). Specifically, the treatments met the guidelines for classrooms used for hearing impaired children, (RT below 0.4seconds from 500Hz-2K) or the higher standard recommended by the British Association of Teacher of the Deaf (RT below 0.4 seconds from 125Hz-4K) (Canning & James 2012).

The results showed the teachers reported a reduction in stress levels, and felt that the teaching environment was better, and they particularly commented on the improvement in behaviour, and comprehension of the children. Of particular note was the improved SNR, and the reduction in noise generated by the pupils, which decreased by nine decibels for every halving of the RT time. This is a significant, because a drop of only three decibels was predicted. The conclusions indicate that in the presence of acoustically dampened classrooms students create less overall noise which implies better behaviour, and more attentive listening, which subsequently allows the teacher to speak less forcefully, thus reducing their vocal exertion

(Canning & James 2012). The results also included a costing analysis for the two highest acoustical upgrades (beyond the minimum requirement) which ranged from to 375-1,475 pound (2009 prices) per 50m2 of classroom.

Given that one of the undesirable effects of background noise on teachers is their heightened incidence of vocal strain in relation to the general population (Sapienza, Crandell & Curtis, 1999). It seems likely that at least part of the issue associated with vocal fatigue is a consequence of the Lombard and Café effects. These two phenomena are highly inter-related, and tend to co-occur, making school classroom environments especially susceptible to their joint effects, as both children and the teacher succumb (albeit unwittingly) to out compete each other and their acoustic environment.

3.05 Importance of the Signal-to-Noise ratio

Signal-to-noise ratio (abbreviated **SNR**) is a quantifiable measure that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, and it is usually expressed in decibels. Essentially, it clarifies the relationship between the power of a signal (desirable information) to the power of background noise (undesirable signal). The following formula is used to calculate a SNR (Moore, 2012).

$$SNR = P(signal) \div P(noise)$$

As an example, if the speech was fifteen decibels louder than the background noise then the SNR is +15dB. The perception of speech is usually better when speech is louder than the noise, and it decreases as the SNR of the location is reduced (Finitzo-Hieber & Tillman, 1978). Normal hearing adults do not usually exhibit difficulties with speech recognition until the SNR is around 0 dB. (Bradley, 1986). Children however require a far greater SNR than adults, due to the immaturity of their general cognitive and auditory processing systems (Boothroyd, 2004). If listeners with a sensori-neural hearing loss are to match the speech recognition of their normal hearing peers, then they need a SNR which is four to twelve decibels greater (Killon, 1997). When the RT of rooms is moderate, then a further three to six decibels improvement in the SNR is required (Hawkins & Yacullo, 1984). These findings indicate that a SNR of +15 is most likely to create an environment for accurate speech recognition in populations with hearing loss.

The interaction of SNR and RT are outlined in the table below which shows that the average speech recognition scores of youngsters with normal hearing and youngsters with a sensori-neural hearing loss using monosyllabic words in a variety of SNR's and RT's. It can be seen that even with a fairly good SNR of +12, and an RT of 0.4 seconds only eighty three percent of the speech is recognized by normal hearing children. Whereas, those with a hearing loss could only manage scores of sixty percent. It should be noted that as the SNR is reduced, and the RT increases the children with normal hearing only perceive thirty percent of the speech signal, and their hearing-impaired counterparts a mere eleven percent! (Finitzo-Hieber & Tillman, 1978).

Table 2: Speech recognition scores from children with and without hearing loss.
Mean speech recognition scores (% correct) by children with normal hearing and children with sensory-neural hearing loss, for monosyllabic words across various SNR and RT values.

		Groups		
Reverberation Time (sec)	*Message-to-Competition Ratio in dB*	*Normal (Loudspeaker-Aided)*	*Hearing-Impaired (Loudspeaker-Aided)*	*Hearing-Impaired (Hearing Aid-Aided)*
0.0	$+\infty$	94.5	87.5	83.0
	+12	89.2	77.8	70.0
	+6	79.7	65.7	59.5
	0	60.2	42.2	39.0
0.4	$+\infty$	92.5	79.2	74.0
	+12	82.8	69.0	60.2
	+6	71.3	54.5	52.2
	0	47.7	28.8	27.8
1.2	$+\infty$	76.5	61.8	45.0
	+12	68.8	50.2	41.2
	+6	54.2	39.5	27.0
	0	29.7	15.3	11.2

(sourced from Finitzo-Hieber & Tillman (1978)

3.06 Critical distance

Another facet which contributes to the levels of speech recognition in the classroom environment is the space between the speaker, and the listener, this is known as the critical distance. This distance has been shown to be approximately three metres from the teacher (Boothroyd, 2004). In a fairly average classroom with seating for thirty-four, the researchers were able to highlight this critical distance by measuring the interplay between speech, RT and SNR. This study used the Rapid Speech Transmission Index (RASTI) and was able to show that eighty three percent of the speech energy was available at the front row of a traditional classroom, whereas, the back row only had access to fifty percent of the speech energy (Leavitt & Flexer, 1991).

One of the reasons that access to speech energy is reduced as the distance from the teacher increases is due to a simple law of physics, known as the Inverse Square Law. Where upon every doubling of distance from the sound source will result in a six decibel decrement in sound level (Moore, 2014). Another factor in this degradation is the impact of reverberation as it encroaches on the direct speech signal altering both its intensity, and spectral shape as the space between the speaker and the listener grows (Crandell & Smaldino, 2000). So, in order to maximise speech perception a child ought to be seated within the critical three metre distance of the teacher (Leavitt & Flexer, 1991; Crandell & Smaldino, 2000). This is especially important for any child with hearing difficulties.

It is likely that seating a child with hearing issues closer to the teacher is feasible where the style of teaching is traditional and didactic. However, this practice of preferential seating may prove to be insufficient given the mobile nature of evolving modern pedagogical practices which encourage the teacher to rove about the room (Bisset, 2014; Wilson, 2015). The inability to maintain this critical distance, and hence maintain a high SNR further explains why hearing aids alone are unlikely to ensure adequate speech clarity can be maintained for any child with hearing difficulties (Wroblewski et al, 2012).

3.07 The Modern Learning Environment & Achievement

The implications from previous research highlight the need for good acoustic design and materials to be used in classrooms in order to minimalize background noise, support the fidelity of speech and reduce the occurrence of reflections; thereby maximising each and every students' opportunity to reach their academic potential.

The advent of MLE's provide an opportunity for those involved in school planning to enhance academic outcomes by creating better learning environments. They reason, that it is illogical to expect high academic performance from pupils who are housed in substandard buildings. In Aotearoa/New Zealand, there is some merit to this argument as the MoE capital stock of classrooms age and require ongoing maintenance, or have weather tightness issues (MoE, 2014a). Healthy environments make an important contribution to teaching and learning, but to what extent remains somewhat elusive, despite a growing body of research into this area (Schneider, 2002).

One such study which was of a size and scale to claim that sixteen percent variation in pupil's academic results could be attributed to the building and design attributes alone. In so doing the investigators claims these results are strong proof of concept (Barrett, et al, 2015). The year long study originated in the United Kingdom, and included a total of 3,766 primary school children across twenty-seven schools and one hundred and fifty three classrooms were followed using a 'Holistic Evidence and Design approach'. This methodology allowed for interactions between the various elements being studied including: flexibility, ownership, colour, light, air quality, temperature, and complexity. They found that half of the improvements in children's learning outcomes could be attributed to the 'naturalness' (air/light/temperature) of these environments, while twenty five percent could be attributed to the 'stimulation' (colour/complexity) of the space, and a further twenty five percent pertained the 'individuality' (flexibility/ownership) these spaces enabled (Barrett, et al, 2015). It is perhaps another demonstration that *"the relationship between school buildings and student health and learning ... is more viscerally understood than logically proven"* (Baker & Berstein, 2012)

In America, an earlier analysis conducted in 2002 examined the literature pertaining to similar environmental factors to see how they related to scholastic performance. Namely, building age and quality, ventilation, thermal comfort, lighting, indoor air quality, school size, class size, and acoustics. The goal was to ascertain which facilities had the most impact on academic progress, and to what extent and degree these features contributed to successful teaching and learning (Schneider, 2002). This paper did focus on the importance of acoustics, unlike the later British investigation by Barrett et al, in 2015. In this study, they were able to cite consistent and well substantiated literature which supported the link between good acoustics and good academic performance (Crandel & Bess, 1986; Crandell et al, 1995; Earthman & Lemasters, 1998; Evans & Maxwell, 1999; Fisher, 2000; Nabelek & Nabelek, 1994; Nelson & Soli, 2000). One interesting aspect which the literature unearthed was the importance teachers attached to classrooms. The educators believed that noise impaired their own academic performance, as it raised their levels of discomfort which subsequently reduced their efficiency. It was mooted that this led to lower quality of teaching and subsequently learning (Lackney, 1999).

Also, worthy of note; the age of a building was not a singular indicator of its likely contribution to academic success or otherwise. The report qualified this by suggesting that some older classrooms provided excellent learning environments (albeit with some modernisation), when compared to newer schools built with tighter budgets (Schneider, 2002). The study also noted that the research debate around ideal class size is ongoing, however, wherever possible, smaller, was preferable. This area requires ongoing research, as many of these studies are used by policy makers to establish trade-offs between planning and design, given that smaller classes require more classrooms or more schools (Schneider, 2002).

After examining the literature, the author surmised that the empirical studies led to a fundamental acknowledgement that school facilities operate within a wide range of variability, and that clean air, good light, along with an environment which was safe, comfortable and quiet were seemingly the most salient physical contributors to academic performance. They stressed that most of these elements were achievable given sufficient funding, competent design, construction, and ongoing maintenance (Schneider, 2002).

The evaluation concluded that despite the increasing body of research examining the impact of school facilities on educational performance, much of the data was inconclusive, and it varied enormously in its quality. They did lament the lack of standardisation within the studies identifying that "*school facilities once translated into bricks-and-mortar affect the daily performance of generations of teachers and students who use them"* (Schneider, 2002).

New Zealand Professor of Education, John Hattie in his synthesis of over eight hundred meta-analyses of achievement was led to conclude that quality teaching has far greater impact on student learning and achievement than other factors such as school structures or class size. (Hattie, 2009). Research does suggest that student teacher-ratios in the vicinity of sixteen to twenty-six are likely to be more effective, which raises concerns about the increased volume of students per teacher associated with MLE's (Wilson, 2015)

In a series of reports commissioned by the NZ Ministry of Education pertaining to MLE's the principle researcher Wall (2015) came to similar conclusions as those of Barrett et al (2015), and Schneider (2002). His research showed that improvements to the physical attributes of a school does affect learning in a positive manner. He did specify that there were no consistent findings as to whether open learning spaces created either positive or negative student outcomes in terms of achievement or engagement. This was attributed to the scope of teaching and learning practices being implemented in these spaces (Wall, 2015). Like other researchers Wall did credit open learning spaces with the flexibility to accommodate different groups of learners thus allowing for a range of different teaching and learning activities to co-occur, which in essence supports student-centric pedagogies (Osborne, 2013; Wall, 2015). Other commentators have stressed that too frequently the architecture of a teaching space may be modern and open, but that does not necessarily mean that the principles of modern learning are in operation. (Campbell et al, 2013; Hattie, 2009; Osborne, 2013; Parnell & Proctor, 2011; Radcliffe et al 2009; Woolner et al, 2012)

4.0 Status of classroom acoustic research

4.0.1 Results of previous acoustic research

The number of studies that have explicitly compared these two types of educational architectural design are surprisingly few, given the upsurge in open teaching spaces. Findings have been mixed, a study from America reported noise levels were on average significantly higher in open plan spaces (Finitizo, 1988). In conflict with this is a study from England where the open designs had five decibels lower average noise levels than the comparable single cell enclosed rooms (Airey, MacKenzie, & Craik, 1998). The researchers conjectured that in this instance there was better acoustical treatment in the open spaces, along with increased vigilance from the teachers regarding noise control.

Another cluster of investigations undertaken in America comparing open and closed teaching spaces exposed very few differences in overall noise levels between the spaces (Barnet et al, 1982; Fitzroy & Reid, 1963; Kyzar, 1971). Interestingly, this trifecta of studies all found the pupils and teachers reported being annoyed by the greater fluctuations in noise levels in open plan spaces compared to the more stable background noise offered by enclosed learning environments (Choudhury, 1973). Some of the variability obtained in these early investigations could plausibly be attributed to methodological differences coupled with structural design differences in the buildings under investigation. In addition, the number of children or home-base clusters involved also varied between the investigations as did the use of dividing partitions which could have impacted on the rooms classification as ‘open’ or ‘semi’ open.

More recent investigations have endeavoured to employ identical methodology between traditional classrooms, and modern open spaces. They have also measured a broader more comprehensive set of factors pertaining to each space reasoning, that it is often the interaction between these aspects which contributes to the overall acoustic performance of a space. (Mealing et al 2015). Factors including:

*Total number of students in space

*Decile rating (SES data)

*Type of space (single cell/semi or fully open/dividers used)

*Number of class bases

*Students per class base

*Room dimensions (m)

*Total floor area (m2)

*Space per child (m2)

*Distance between edge of class bases

*Height of ceiling (m)

*Overall room volume (m^3)

4.0.2 Results of current acoustic research

A recent soon to be published study undertaken in Christchurch NZ examined a mixture of primary school classrooms known as “learning hubs” and MLE. The unoccupied ambient noise levels (ANL) ranged from 26-51dBA. Occupied sound levels were logged for the entire school day (9am-3pm). During this time, the noise levels ranged between 35-95 (LAeq dBA), with an overall average of 63-67 (LAeq dBA) (Pearse, 2018)

Researchers in Brisbane, Australia, recently evaluated the 'acoustic health' of a total of thirty-three classrooms including nineteen single cell rooms, and fourteen dual cell spaces, with volumes ranging from sixty-nine to three hundred and seventy-eight square metres (Wilson et al 2018). The findings showed that the unoccupied sound levels exceeded the AS/NZS 2107:2016 recommendation in twenty two percent of classrooms. Alarmingly, seventy nine percent of rooms exceeded RT outlined in the above standard. When a further twelve rooms were re-sampled, ninety-two per cent of these indicated occupied noise levels above the recommended maximum of fifty dB LAeq (averaged A weighted noise over time) (Mealings, 2016). Additionally, ninety two percent of rooms yielded speech transmission scores below the 0.75 level needed for young primary school children (Greenland & Shield, 2011; Mealings, 2016).

The conclusions reached by Wilson et al was that the majority of teaching spaces in their Brisbane study had unsuitable acoustics for young children to learn well in. They attributed most of these issues to aspects of building design and materials. The findings are consistent with similar reports from around the world (Crandell & Smaldino, 2000; Shield & Dockrell, 2004; Wilson et al, 2011). These findings add to the ever-increasing list of professional international bodies calling for substantial improvements to classroom acoustics, including: Acoustical Society of America (2003a, b; National Acoustics Laboratories, 2018; The HEARing Cooperative Research Centre, 2018)

Throughout the world, a variety of standards apply to the acoustic requirements for classrooms. In 2015, a comprehensive review of international literature and experimental studies was undertaken by Kiri Mealings from the National Acoustics Laboratories in Australia. (Mealings, 2016) A summary of these findings are reproduced here with kind permission of Kiri Mealings. This exhaustive study made it possible to make judgements and establish a rating system for classrooms in regard to the suitability of their acoustic parameters for children of various ages, including those youngsters with special needs.

Table 3: Overall acoustic recommendations for primary school classrooms (from Mealing, 2016)

Rating	Unoccupied ANL (dBA)	Occupied BNL (dBA)	SNR (dB)	RT (s) (unoccupied)	STI
Good	< 30 dBA	< 50 dBA	> +15 dB	< 0.4 s	> 0.75
OK	30-40 dBA	50-55 dBA	+10 to +15 dB	0.4-0.6 s	0.6-0.75
Bad	> 40 dBA	> 55 dBA	< +10 dB	> 0.6 s	< 0.6

Table 4: Acoustic recommendations for primary school classrooms for children at different ages. (from Mealing, 2016)

Age Group	Rating	Unoccupied ANL (dBA)	Occupied BNL (dBA)	SNR (dB)	RT (s) (unoccupied)	STI
6-7 years	Good	< 28 dBA	< 45 dBA	> +20 dB	< 0.4 s	> 0.75
	OK	28-35 dBA	45-50 dBA	+15 to +20 dB	0.4-0.6 s	0.7-0.75
	Bad	> 35 dBA	> 50 dBA	< +15 dB	> 0.6 s	< 0.7
8-9 years	Good	< 35 dBA	< 47 dBA	> +18 dB	< 0.4 s	> 0.7
	OK	35-40 dBA	47-53 dBA	+12 to +18 dB	0.4-0.6 s	0.6-0.7
	Bad	> 40 dBA	> 53 dBA	< +12 dB	> 0.6 s	< 0.6
10-11 years	Good	< 39 dBA	< 50 dBA	> +15 dB	< 0.4 s	> 0.61
	OK	39-40 dBA	50-56 dBA	+9 to +15 dB	0.4-0.6 s	0.6-0.61
	Bad	> 40 dBA	> 56 dBA	< +9 dB	> 0.6 s	< 0.6
12+ years	Good	< 40 dBA	< 50 dBA	> +15 dB	< 0.4 s	> 0.61
	OK	40-45 dBA	50-56 dBA	+9 to +15 dB	0.4-0.6 s	0.6-0.61
	Bad	> 45 dBA	> 56 dBA	< +9 dB	> 0.6 s	< 0.6

Table 5: Acoustic recommendations for primary school classrooms with hearing/lang. impaired children, (from Mealing, 2016)

Rating	Unoccupied ANL (dBA)	Occupied BNL (dBA)	SNR (dB)	RT (s) (unoccupied)	STI
Good	< 20 dBA	< 40 dBA	> +20 dB	< 0.3 s	> 0.75
OK	20-30 dBA	40-45 dBA	+15 to +20 dB	0.3-0.5 s	0.6-0.75
Bad	> 30 dBA	> 45 dBA	< +15 dB	> 0.5 s	< 0.6

6.0 Summary

Increasingly globalisation, along with substantial economic, societal and technological advances have led to an overhaul of many educational and pedagogical practices (Bolstead, 2012). Computers, and other digital developments have exponentially raised the quantity and quality of information available to humanity (Bolstead, 2012). One of the consequences of this rapidly evolving information age, has been the need to re-think the applicability of previous educational paradigms. Particularly with a view to preparing students to enter a world which is increasingly complex, technologically sophisticated, and in a constant state of flux (Bolstead, 2012).

The education model, in Aotearoa – New Zealand, like many others around the world was largely premised on a paradigm which viewed children as passive receptacles for knowledge (Hattie, 2009). This was reflected in the physical design of educational facilities which were composed of classrooms arranged to support a "stand and deliver" style of teaching (Bolstad, 2012). In contrast, research demonstrated that educational outcomes were more likely to improve when learning encouraged a more active, engaged approach to the acquisition of knowledge (Hattie, 2009)

The Ministry of Education's response to these pedagogical changes was to invoke a new style of open-plan classroom environment, which would allow for greater flexibility and fluidity for both teachers and learners alike. The structural changes to classrooms would be characterised by voluminous spaces, which were densely populated, and yet facilitated an increase in group activities. Progressively primary schools throughout Aotearoa – New Zealand would be furnished with these modern learning environments or MLE. All schools would be required to include this style of teaching facility into their ten-year property plan as a pre-requisite to ongoing capital funding from the Ministry (Wilson, 2015)

Previously, during the 1970's open plan style classrooms had been trialled, and largely rejected due to the subsequent noise levels associated with this style of architecture (Bisset, 2014). Long reverberation times, and undue background noise have the capability of negatively impacting children's overall scholastic performance; particularly in the areas of numeracy and literacy (Mackenzie, 1999; Maxwell & Evans, 2000). The current MLE are to be constructed under the auspices of a 2016 Ministry of Education document entitled "Designing Quality Learning Spaces"v2 – Acoustics. The provisions of this paper stipulate certain acoustic parameters which must be met, and others which are recommended. However, these new guidelines, only apply to buildings commencing construction in 2017.

Previous investigations into noise levels found in different styles of classrooms are not unanimous (Barnett, Nichols, & Gould, 1982; Finitzo TJ Roeser RJ 1988; Fitzroy & Reid, 1963; Kyzar, 1971; MacKenzie, 1999). It was of interest to this author to ascertain the current acoustic health of a sample of both MLE and TRADitional classrooms to assess how well they performed according to the DQLS suggestions, alongside two other international indices. Specifically, the Australian, Department of Education, in New South Wales, which has encapsulated its acoustic guidelines in the “Sound-Out” App. Also, the Mealing 2016 paper which is a substantive evaluation of International Academic research that culminated in the publication of a series of tables with recommendations of suitable acoustic parameters for the education of primary school aged children. The current author felt that this data would not only document the current status of learning environments for young children in NZ, but that the results might also inform future management of teaching spaces for all youngsters particularly with a view to meeting the goals of “inclusive” education.

AIMS AND HYPOTHESES

This thesis aimed to examine the acoustic parameters of both traditional and modern learning environments in schools in the Canterbury region. The purpose of this investigation was to ascertain whether these measurements met the guidelines published recently by the NZ Ministry of Education "Designing Quality Learning Spaces v2" (2016).

In addition, this study was designed to grade the classrooms using two other sets of acoustic recommendations, one from Australia and one International scale. By benchmarking the classrooms against a total of three indices, it was hoped to better understand the acoustic health of some NZ classrooms in which primary school children are being educated. Based on the findings of previous research (Wilson, 2002; Mealing, 2015, Mealing 2016) this study intended to answer five research questions and four hypotheses which are outlined on the following page. Subsequent to the testing of these hypotheses, it would be possible to answer question five regarding the "over-all" acoustic health of the classrooms under consideration.

Research Questions and Hypotheses

Q1 What are typical unoccupied ambient noise levels (ANL); unoccupied Reverberation Times (RT); occupied background noise levels (BNL); occupied speech transmission index scores (STI); in traditional cellular classrooms (TRAD) and Modern Learning Environments (MLE) in, NZ, and how do they rate against International/Australian/NZ recommendations?

Hypothesis A = H_0 Scores for Traditional classrooms (TRAD) will not be significantly different to modern learning environments (MLE) over a range of parameters specifically: "ANL" ,"BNL", "RT" and "STI" (Ambient Noise Level/Background Noise Level/Reverberation Time/Speech Transmission Index).

Q2 Is there a relationship between the number of pupils in a classroom, and the levels of background noise?

Hypothesis B = H_0 There will be no significant correlation between the number of children in a class and the occupied background noise levels (BNL).

Q3 Are the different acoustic needs of younger children reflected in their classrooms?

Hypothesis C = H_0 There is no significant difference in any of the acoustic parameters ("ANL", "BNL", "RT" and "STI") for younger or older age groups

Q4 Are children in NZ with identified hearing/language impairments being taught in classrooms with acoustic which accommodate their hearing and listening needs?

Hypothesis D = H_0 There will be no significant difference in any of the acoustic parameters found in classrooms where children with identified hearing/language impairments are taught.

Q5 When "ANL" "BNL" "RT" and "STI" are considered altogether, do MLE or TRAD rooms meet "overall" recommendations specified in the Australian, or International scales. (ambient noise level/background noise level/reverberation time/speech transmission index.

METHODOLOGY

6.0 Ethical Approval

Approval to conduct this study was obtained from the University of Canterbury Educational Research Human Ethics Committee (see Appendix A). The procedures used to conduct this study were carried out in accordance with their approval. All participants received study information sheets and had electronically signed consent forms prior to their involvement in this study.

6.1 Study design

This study uses an experimental design where the four dependent variables under investigation include the “ambient” and “background” noise levels along with the RT (reverberation time), the STI (Speech Transmission Index). The independent variable is the classroom acoustics.

6.2 Participants

School Principals within the greater Christchurch area will be canvassed to volunteer their classrooms for testing. A range of schools, both public and private with different decile ratings will be included. A random sample from this group will then be selected to participate giving a total of twenty classrooms for testing. A cross section of traditional cellular classrooms and MLE (modern learning environments) will be assessed. The inclusion criteria restricted classroom spaces to those used to teach youngsters in either year one or year two. The rationale for this is informed by earlier research which noted weaker auditory-neurophysiological response to consonant-vowel syllables in the presence of background noise when compared to quiet conditions (White-Schwoch et al, 2015). Children in years three and four are also susceptible to these cognitive difficulties in higher background noise, but the younger pupils are especially vulnerable, hence it was decided to restrict testing to rooms which housed learners aged between 5-7 years only.

Prior to any research commencing, teachers confirmed their willingness to participate in the study by signing an electronic consent form which included an information sheet.

A priori G*power analysis was used to determine the required sample size for this research. This was calculated using an effect size of 0.8, to achieve a Cohens d of 0.5 a total sample size of 106 classrooms was recommended (n=106), even to achieve a Cohens d of 0.75 a total sample size of 48 classrooms was recommended (n=48). A combination of logistical, financial and temporal considerations meant that it was only feasible for this study to examine a total of 22 classrooms (11 traditional, and 11 MLE).

6.3 Sampling

The most recent school directory was downloaded from the "Education Counts" website (http://www.educationcounts.govt.nz/home). All Secondary schools were removed from the list using Microsoft excel 2010 to differentiate them from Primary Schools. Next the schools which had earlier consented to be contacted for research, were further pared down to those within the wider Canterbury region or Christchurch city itself. Subsequently, each remaining school was assigned a number and a random number generator created a group of twenty numbers at a time. Pursuant to this, electronic letters were sent to each group of twenty randomly selected school principals asking for classrooms and their teachers to be involved in this study. This process continued until the requisite 22 classrooms were obtained.

6.4 Preliminary Trial

The "SOUND-OUT" app was calibrated by Marshall Day Acoustics, an independent firm of professional Acoustic Engineers, to ensure it was measuring accurately. A Bruel & Kjaer

Sound Level Meter (type 2231) was used for the calibration testing, with pink noise from a Neutrik Signal generator acting as the signal source. (see appendix)

A number of classrooms were tested prior to the commencement of the official research measurements. This was to ensure procedural accuracy, and calibration measures were standardised wherever possible. Management of the records, and data storage were also fine-tuned.

6.5 Experimental Design

This study employed a between group design to analyse the acoustical parameters found in MLE, and TRAD classrooms in the city of Christchurch, NZ.

6.6 Measures

This study will be measuring four factors within each type of classroom (traditional/MLE). Firstly, the "ambient noise" (ANL) within the unoccupied classroom environment. Secondly the background noise level (BNL) in the occupied classroom when children are working independently (either writing or reading). Thirdly, the RT or "reverberation time". Lastly, the "speech transmission index" (STI). The dependent variables under investigation are the "ANL", "BNL", "RT" and "STI" and the independent variable is the classroom acoustics/architecture TRAD or MLE.

6.7 Procedure

A series of acoustical measures will be taken in each classroom using the 'SOUND-OUT' Room Acoustic Analyser, which was specifically created for measuring school classrooms. It was designed by acoustic engineers at the National Acoustics Laboratory (NAL) based at Macquarie University, Sydney, Australia. Version 1:02 of the applications (APP) will be running on an Apple I-Pad 3:1 running IOS software version 9:3:5. The I-Pad will be positioned 1.5m from the floor, with the omnidirectional microphone facing up toward the ceiling in each classroom. Three different measurements will be made in each classroom. The first will be the "ANL" which will include the general noise of the unoccupied classroom including such things as: computers, fish tanks, heat pumps, projectors, general equipment). An "A" weighted SLM (sound level meter) built into the "SOUND-OUT" app measured the levels for a duration of approximately 10 minutes, then a final level in dBA will be automatically calculated, along with a "traffic light" rating of **'GOOD' in green**, **'OK' in orange**, or **'BAD' in red**.

The second acoustic parameter will be the "BNL" which will include the general background noise of the occupied classroom, plus any noise generated in the room during a classroom activity where the children are working independently, preferably writing, or reading, or colouring in. An "A" weighted SLM (sound level meter) built into the "SOUND-OUT" app will measure the levels for a total duration of approximately 15 minutes; comprised of three five minute recordings in different positions throughout the room. Subsequently, a final numerical reading in dBA will be automatically calculated by the app. along with a "traffic light" rating of **'GOOD' in green**, **'OK' in orange**, or **'BAD' in red**.

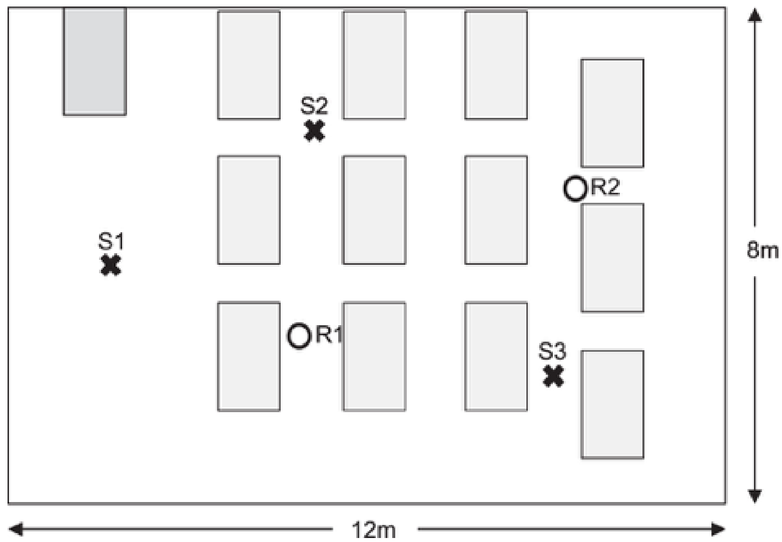


Figure 4: Measurement configuration for (x3) Background Noise Level readings, in a TRADitional classroom.
(X= i-pad Site 1, Site 2, Site 3). (O=Observer/Researcher position 1, position 2)
(adapted from Shield & Conetta, 2015)

The third measure will be of the RT (reverberation time) in each unoccupied classroom. The RT will be measured using the "SOUND-OUT" APP, a customised classroom acoustic app designed by the National Acoustic Laboratories (NAL) at Macquarie University, Sydney Australia, in conjunction with the New South Wales Education Department. This time decay program was developed by Dr Jorg Bucholtz et al. He programmed the reverberation time using the integrated impulse response method, in accordance with the: International Standard: ISO 3382-2 (2008), Acoustics – Measurement of room acoustic parameters – Part 2: Reverberation Time in ordinary rooms.

This will be assessed by placing the i-Pad in the centre of the classroom and, a balloon pop will be performed where the teacher spends the majority of their teaching time within that space. The SOUND-OUT app will measure the time it takes for the "pop" to decay by 60dB(A). A popping balloon is a suitable stimulus to measure since it provides a broadband impulse sound which has an identifiable peak SPL (sound pressure level). It also guarantees a decay curve which commences at least 60dB over the background noise. Depending on the available dynamic range (in octave bands) the T30 or T20 was used to calculate the RT. Only measurement with an available dynamic range of >35dB produce an output.

The RT will be reported as an average for 500Hz, 1KHz, and 2KHz, known as the Mid Frequency Response. The RT60 will automatically be calculated by the app. and reported as a numerical reading along with a "traffic light" rating of **'GOOD' in green**, **'OK' in orange**, or **'BAD' in red**.

The fourth reading will be the "STI" (Speech Transmission Index) which indicates how much of speech is likely to be available to listeners in the room during a classroom activity. The STI algorithm used in the SOUND-OUT app was originally based on an implementation by Associate Professor Densil Cabrera and colleagues, University of Sydney, see: Cabrera, D., Jimenez, D. and Martens, W.L., Audio and Acoustical Response Analysis Environment (AARAE): a tool to support education and research in acoustics, Proceedings of Internoise, Melbourne, Australia, 2014.

The STI calculations incorporated into the SOUND-OUT app were programmed and verified according to: International standard: IEC 60268-16 (2011), Sound system equipment – Part 16: Objective rating of speech intelligibility by speech transmission index. As the STI is gender-dependent, the SOUND-OUT app averages the STI values across both male and female speech. The SOUND-OUT app is programmed on the assumption that a teacher's average speech level is 61 dBA (or 63.5 dBSPL) with an octave-band spectrum of Lspeech = [43.2 57 60.13 56.84 51.3 45.76 37.05] dBSPL at centre frequencies of fc = [125, 250, 500, 1000, 2000, 4000, 8000] Hz.

The STI score is reported numerically. For the sake of consistency, and ease of interpretation, the researcher will subsequently also grade the STI value using the “traffic light” rating of **‘GOOD’ in green**, **‘OK’ in orange**, or **‘BAD’ in red**. The grading will be reported according to the different criteria specified by the NSW Dpt of Education, and the International Mealings recommendations.

These recordings will be supported by visual and written information about each classroom, namely photographs an (including building materials, soft furnishing, architectural details etc. these will be included in the appendix of the final thesis.)

6.8 Data Collection

Measurements captured in each teaching space yielded roughly 70 MB (15 minutes long) of data. Each of the four measurements under consideration were stored as individual files relating to a specific classroom. These files were then tabulated into an Excel spreadsheet for subsequent analysis. These files were also written to a USB stick.

6.9 Statistical analysis of data

The data generated by this research was exported into Microsoft Excel 2016, and subsequently analysed via the IBM (International Business Machines) Statistical Package for the Social Sciences version 24 (IBM2017) to decide the statistical significance of the results.

Descriptive statistics were employed to analyse research questions 1-4. The results are presented graphically as percentages for each of the following three entities who’ve published acoustic recommendations/ratings suitable for children to learn in, i.e., the NZ MoE DQLS recommendations, the Australian, MoE in NSW SoundOut App, The International recommendations found in the Mealings study (2016).

Statistical analysis was conducted using nonparametric tests, due to the presence of skewness and kurtosis across all the acoustic parameters under consideration. These tests do not assume the sample groups will be normally distributed.

A Mann Whitney test was used for Research question 5 to assess whether there was any significant difference found between MLE and TRAD classroom across all the four parameters tested “ANL”, “BNL”, “RT” and “STI” (Ambient Noise Level / Background Noise Level / Reverberation Time / Speech Transmission Index)

A Kruskal-Wallis test was employed for Research question 6, to assess whether there was any significant difference between younger or older age groups across all the parameters tested, including “ANL”, “BNL”, “RT” and “STI” (Ambient Noise Level/Background Noise Level / Reverberation Time/Speech Transmission Index).

A Spearman’s correlation was utilised for Research question 7, to ascertain whether there was any statistical dependence between the rankings of two variables, specifically, the number of children in a teaching space and the level of background noise.

RESULTS

The first half of the results section focuses purely on the descriptive statistics and classroom ratings derived from the use of the three different scales. These results relate to Research Question One. The second half of the results section reports the findings from each of the four hypotheses under consideration.

Q1 What are typical unoccupied ambient noise levels (ANL); unoccupied Reverberation Times (RT); occupied background noise levels (BNL); occupied speech transmission index scores (STI); in traditional cellular classrooms (TRAD) and Modern Learning Environments (MLE) in, NZ, and how do they rate against International/Australian/NZ recommendations?

7.0 Ambient Noise Levels (ANL)

7.0.1 Ambient Noise Levels (unoccupied MLE)

Descriptive statistical analysis from the 11 MLE revealed the following. Minimum of 33.5 dBA, Maximum of 50.3 dBA, Mean of 40.2, Standard Deviation of 5.21, Median of 38.9.

*Table 6: The unoccupied **Ambient Noise Levels (ANL)** recorded in **MLE** classrooms in this study, and the recommended levels & ratings by NZ MoE, the Australian Dpt of Education in NSW, and the International (Mealings study),*

CLASS (N=11)	ANL READING (dBA)	**NEW ZEALAND (MoE DQLS)** Recommendation GOOD = < 35 dBA OK = 35-45 dBA BAD = > 45 dBA	**AUSTRALIAN (NSW- Dpt of Ed)** Recommendation GOOD = < 40 dBA OK = 40-45dBA BAD = > 45 dBA	**INTERNATIONAL (MEALINGS)** Recommendation GOOD = < 30 dBA OK = 30-40dBA BAD = > 40 dBA
1	42.9	OK =Orange	OK =Orange	BAD =Red
2	50.3	BAD =Red	BAD =Red	BAD =Red
3	37.8	OK =Orange	GOOD =Green	OK =Orange
4	38.9	OK =Orange	GOOD =Green	OK =Orange
5	41.4	OK =Orange	OK =Orange	BAD =Red
6	40	OK =Orange	OK =Orange	OK =Orange
7	37.8	OK =Orange	GOOD =Green	OK =Orange
8	34.5	GOOD =Green	GOOD =Green	OK =Orange
9	37	OK =Orange	GOOD =Green	OK =Orange
10	48	BAD =Red	BAD =Red	BAD =Red
11	33.5	GOOD =Green	GOOD =Green	OK =Orange
Min	33.5			
Max	50.3			
Mean	40.19			
Std. Dev	5.21			
Median	38.9			

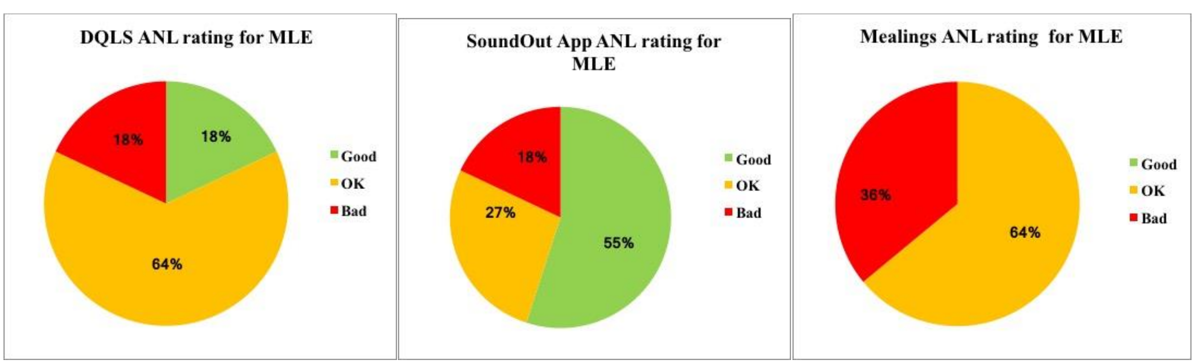
The upper limit for ambient noise levels (ANL) recommenced by the NZ MoE DQLS is 45 LAeq, dB (A). Analysis of the eleven MLE classrooms under investigation revealed the following: Two classrooms recorded ANL levels below 35dBA, which corresponds to a ‘good’ rating indicted by the green writing. Seven MLE were within the MoE recommended range of 35-45 dBA, which is indicated by the orange “OK” rating, and two MLE recorded ANL above 45dBA which is indicated by the “bad” rating in red. Overall, 9 of the 11 (82%) MLE in this investigation met the DQLS requirements, for acceptable ANL, and two (18%) did not.

Based on the AUSTRALIAN SOUNDOUT CLASSROOM ACOUSTIC APP, 6 of the 11 (55%) the MLE in this study had ‘good’ green ratings, that is the unoccupied ambient noise in the classrooms was below forty dBA. A further 3 of the 11 (27%) had ambient noise levels between 40-45 dBA which corresponds to an ‘OK’ rating. Additionally, 2 of the 11 (18%) classrooms had ANL greater than 45dBA which is indicated by the “bad” rating. Overall, 9 of the 11 (82%) MLE in this investigation met the Australian SoundOut App requirements, for acceptable ANL, and two (18%) did not.

Re-evaluating the same group of classrooms based on the more stringent INTERNATIONAL MEALINGS CLASSIFICATION, showed none of the MLE in this study met the Mealings criteria for a ‘good’- ‘green’ rating for unoccupied noise levels which were below thirty dBA. Just over half the MLE, 7 of the 11 (64%) achieved an ‘OK’ or orange rating. That is the unoccupied ambient noise in the classrooms was below forty dBA. A further 3 of the 11 rooms recorded ANL in excess of 40dBA which meant they scored a ‘Bad’ red rating. Overall, 7 of the 11 (64%) MLE in this investigation met the International Mealing Classification requirements for acceptable ANL.

These results are represented graphically in figure 5

Figure 5: Pie charts showing the results of three different rating scales for Ambient Noise Levels in MLE



7.02 Ambient Noise Levels (unoccupied TRAD)

Descriptive statistical analysis from the 11 TRAD revealed the following. Minimum of 34.4 dBA, Maximum of 43.1 dBA, Mean of 37.0, Standard Deviation of 2.7, Median of 36.5.

*Table 7: The unoccupied **Ambient Noise Levels (ANL)** recorded in **TRAD** classrooms and the recommended levels & ratings by NZ MoE, The International (Mealing study), and the Australian Dpt of Education in NSW.*

CLASS (N=11)	ANL READING (dBA)	**NEW ZEALAND (MoE DQLS)** Recommendation GOOD = < 35 dBA OK = 35-45dBA BAD = > 45 dBA	**AUSTRALIAN (NSW- Dpt of Ed)** Recommendation GOOD = < 40 dBA OK = 40-45dBA BAD = > 45 dBA	**INTERNATIONAL (MEALINGS)** Recommendation GOOD = < 30 dBA OK = 30-40dBA BAD = > 40 dBA
12	38.2	OK =Orange	GOOD =Green	OK =Orange
13	40.2	OK =Orange	OK =Orange	BAD =Red
14	34.7	GOOD =Green	GOOD =Green	OK =Orange
15	43.1	OK =Orange	OK =Orange	BAD =Red
16	37.1	OK =Orange	GOOD =Green	OK =Orange
17	37.6	OK =Orange	GOOD =Green	OK =Orange
18	34.4	GOOD =Green	GOOD =Green	OK =Orange
19	34.6	GOOD =Green	GOOD =Green	OK =Orange
20	35.3	OK =Orange	GOOD =Green	OK =Orange
21	35.3	OK =Orange	GOOD =Green	OK =Orange
22	36.5	OK =Orange	GOOD =Green	OK =Orange
Min	34.40			
Max	43.10			
Mean	37			
Std. Dev	2.70			
Median	36.5			

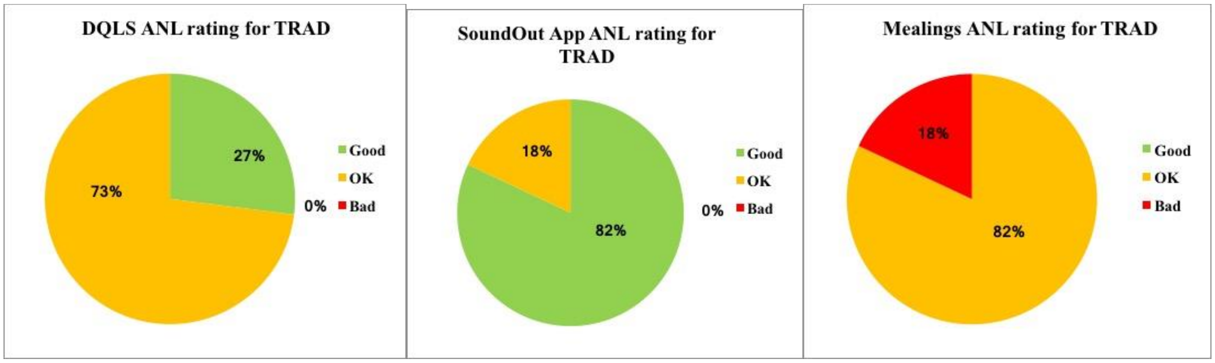
The upper limit for ambient noise levels (ANL) recommenced by the NZ MoE DQLS is 45 LAeq, dB (A). Analysis of the eleven TRAD classrooms under investigation revealed the following: 3 of the 11 (27%) classrooms recorded ANL levels below 35dBA, which corresponds to a ‘good’ rating indicted by the green writing. A total of 8 of the 11 (73%) TRAD rooms were within the MoE recommended range of 35-45 dBA, which is indicated by the orange "OK" rating. No TRAD rooms recorded ANL above 45dBA which is indicated by the "bad" rating in red. Overall, 11 of the 11 (100%) TRAD rooms in this investigation met the NZ MoE DQLS requirement for acceptable ANL.

Based on the AUSTRALIAN SOUNDOUT CLASSROOM ACOUSTIC APP, 9 of the 11 (82%) the MLE in this study had 'good' green ratings, that is the unoccupied ambient noise in the classrooms was below forty dBA. A further 2 of the 11 (18%) had ambient noise levels between 40-45 dBA which corresponds to an 'OK' rating. No TRAD rooms recorded ANL above 45dBA which is indicated by the "bad" rating in red. Overall, 11 of the 11 (100%) TRAD rooms in this investigation met the Australian SoundOut App requirements for acceptable ANL.

Re-evaluating the same group of classrooms based on the more stringent INTERNATIONAL MEALINGS CLASSIFICATION, showed none of the TRAD rooms in this study met the Mealings criteria for a 'good'- 'green' rating for unoccupied noise levels which were below thirty dBA. Just over half the MLE, 9 of the 11 (82%) achieved an 'OK' or orange rating. That is the unoccupied ambient noise in the classrooms was below forty dBA. A further 2 of the 11 rooms recorded ANL in excess of 40dBA which meant they scored a 'Bad' red rating. Overall, 9 of the 11 (82%) TRAD rooms in this investigation met the International Mealings Classification requirements for acceptable ANL.

These results are represented graphically in figure 6

Figure 6: Pie chart showing the results of three different rating scales for Ambient Noise Levels in TRADitional classrooms.



7.1 Reverberation Time (RT)

7.1.1 Reverberation Time (unoccupied MLE)

Descriptive statistical analysis from the 11 MLE revealed the following. Minimum of 0.36 seconds, Maximum of 0.65s, Mean of 0.45s, Standard Deviation of 0.08, Median of 0.42 s.

Table 8: The unoccupied ***Reverberation Time (RT)*** *recorded in MLE classrooms and the recommended levels & ratings by NZ MoE, The International (Mealings study), and the Australian Dpt of Education in NSW.*

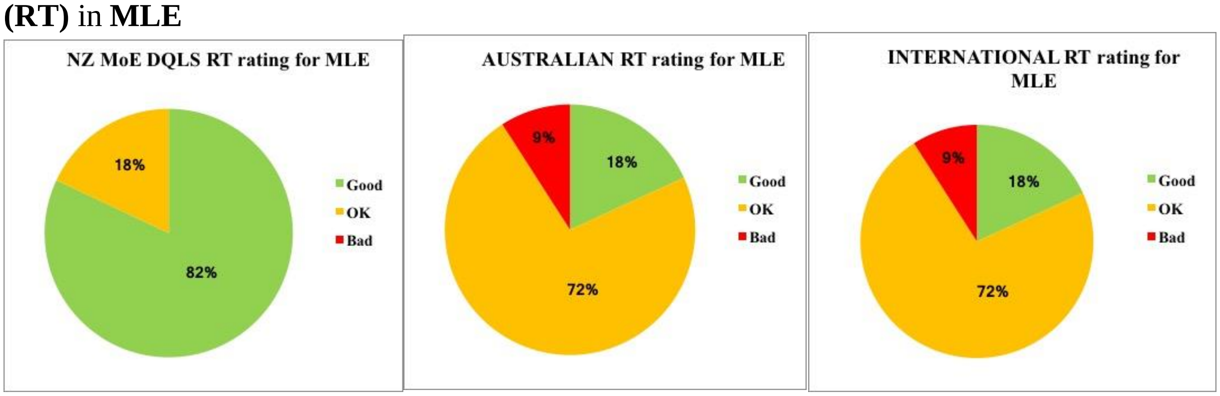
CLASS (N=11)	RT READING (T30 sec)	**NEW ZEALAND (MoE DQLS)** Recommendation GOOD = < 0.50 sec OK = 0.5-0.8 sec BAD = > 0.80 sec	**AUSTRALIAN (NSW- Dpt of Ed)** Recommendation GOOD = < 0.40 sec OK= 0.40-0.60 sec BAD = > 0.60 sec	**INTERNATIONAL (MEALINGS)** Recommendation GOOD = < 0.40 sec OK= 0.40-0.60 sec BAD = > 0.60 sec
1	0.50	GOOD =Green	OK =Orange	OK =Orange
2	0.42	GOOD =Green	OK =Orange	OK =Orange
3	0.41	GOOD =Green	OK =Orange	OK =Orange
4	0.39	GOOD =Green	GOOD =Green	GOOD =Green
5	0.43	GOOD =Green	OK =Orange	OK =Orange
6	0.42	GOOD =Green	OK =Orange	OK =Orange
7	0.41	GOOD =Green	OK =Orange	OK =Orange
8	0.46	GOOD =Green	OK =Orange	OK =Orange
9	0.36	GOOD =Green	GOOD =Green	GOOD =Green
10	0.65	OK =Orange	BAD =Red	BAD =Red
11	0.56	OK =Orange	OK =Orange	OK =Orange
Min	0.36			
Max	0.65			
Mean	0.45			
Std. Dev	0.08			
Median	0.42			

The upper limit for Reverberation Times (RT) recommenced by the NZ MoE DQLS is 0.8 seconds, (volume dependant, m^3 - see pg. 13 DQLS). Analysis of the MLE classrooms under investigation revealed the following: 9 of the 11 (82%) classrooms recorded RT levels below 0.5 seconds, which corresponds to a ‘good’/green rating. A further 2 of the 11 (18%) MLE were within the MoE recommended range of 0.5-0-8 seconds, which is indicated by the “OK”/orange rating. None of the MLE recorded RT above 0.8 seconds which is indicated by the “bad”/red rating. Overall, 11 of the 11 (100%) of the MLE in this investigation met the DQLS requirements, for acceptable RT.

Based on the AUSTRALIAN SOUNDOUT CLASSROOM ACOUSTIC APP, 2 of the 11 (18%) of the MLE in this study had ‘good’ green ratings, that is the RT in the classrooms was below 0.4 seconds. A further 8 of the 11 (72%) had RT between 0.4-0.6 seconds which corresponds to an ‘OK’/orange rating. Additionally, 1 of the 11 (9%) classrooms had a RT greater than 0.6 seconds which is indicated by the “bad”/red rating. Overall, 10 of the 11 (90%) of MLE in this investigation met the Australian SoundOut App requirements, for acceptable RT.

Evaluating the same group of classrooms using the INTERNATIONAL MEALINGS CLASSIFICATION, showed 2 of the 11 (18%) of the MLE in this study met the Mealings criteria for a ‘good’- ‘green’ rating for RT which was below 0.4 seconds. A further, 8 of the 11 (72%) achieved an ‘OK’ or orange rating. That is the unoccupied RT in the classrooms was between 0.4-0.6 seconds. Additionally, 1 of the 11 rooms recorded RT in excess of 0.6 seconds which meant it scored a ‘Bad’ red rating. Overall, 10 of the 11 (90%) of MLE in this investigation met the International Mealings Classification requirements for acceptable RT. These results are represented graphically in figure 7

Figure 7: Pie chart showing the results of three different rating scales for **Reverberation Time (RT)** in **MLE**



7.1.2 Reverberation Time (unoccupied TRAD)

Descriptive statistical analysis from the 11 TRAD revealed the following. Minimum of 0.39 seconds, Maximum of 0.62s, Mean of 0.49s, Standard Deviation of 0.78, Median of 0.48 s.

These were an average measured across the mid frequency range (500Hz/1000Hz/2000Hz.)

Table 9: The unoccupied ***Reverberation Time (RT)*** *recorded in* ***TRAD*** *classrooms and the recommended levels & ratings by NZ MoE, The International (Mealings study), and the Australian Dpt of Education in NSW.*

CLASS (N=11)	RT TIME seconds	**NEW ZEALAND (MoE DQLS)** Recommendation GOOD = < 0.40 sec OK = 0.4-0.5 sec BAD => 0.50 sec	**AUSTRALIAN (NSW- Dpt of Ed)** Recommendation GOOD = < 0.40 sec OK= 0.40-0.60 sec BAD => 0.60 sec	**INTERNATIONAL (MEALINGS)** Recommendation GOOD = < 0.40 sec OK= 0.40-0.60 sec BAD => 0.60 sec
12	0.50	OK =Orange	OK =Orange	OK =Orange
13	0.60	RED =BAD	RED =BAD	RED =BAD
14	0.62	RED =BAD	RED =BAD	RED =BAD
15	0.48	OK =Orange	OK =Orange	OK =Orange
16	0.47	OK =Orange	OK =Orange	OK =Orange
17	0.47	OK =Orange	OK =Orange	OK =Orange
18	0.40	GOOD =Green	GOOD =Green	GOOD =Green
19	0.41	OK =Orange	OK =Orange	OK =Orange
20	0.50	OK =Orange	OK =Orange	OK =Orange
21	0.56	RED =BAD	OK =Orange	OK =Orange
22	0.39	GOOD =Green	GOOD =Green	GOOD =Green
Min	0.39			
Max	0.62			
Mean	0.50			
Std. Dev	0.08			
Median	0.48			

The upper limit for Reverberation Times (RT) in TRAD classrooms recommenced by the NZ MoE DQLS is 0.5 seconds. Analysis of the TRAD classrooms under investigation revealed the following: 2 of the 11 (18%) classrooms recorded RT levels below 0.4 seconds, which corresponds to a ‘good’/green rating. A further 6 of the 11 (55%) TRAD classrooms were within the MoE recommended range of 0.4-0-5 seconds, which is indicated by the “OK”/orange rating.

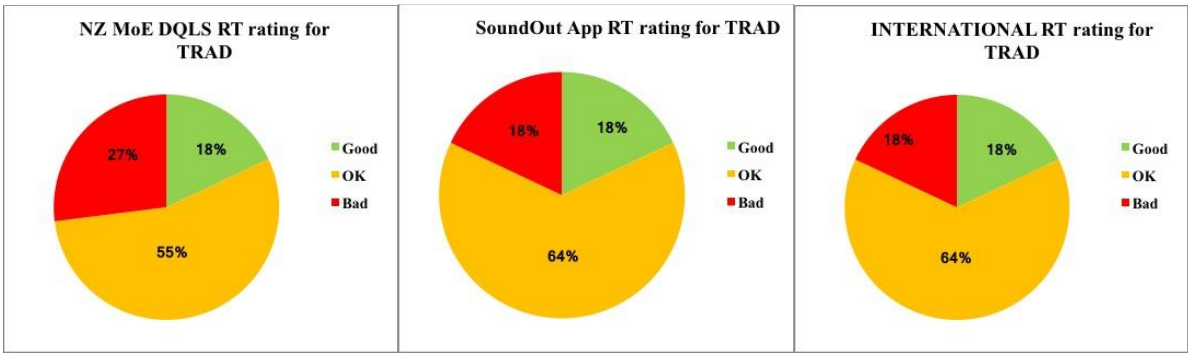
Additionally, 3 of the 11 (27%) rooms recorded RT in excess of 0.5 seconds which meant they scored a 'Bad' red rating. Overall, 8 of the 11 (72%) of the TRAD rooms in this investigation met the DQLS requirements, for acceptable RT.

The upper limit for Reverberation Times (RT) in TRAD classrooms recommended by the AUSTRALIAN SOUNDOUT CLASSROOM ACOUSTIC APP is 0.6 seconds. So, 2 of the 11 (18%) TRAD rooms in this study had 'good' green ratings, that is the RT in the classrooms was below 0.4 seconds. A further 7 of the 11 (64%) had RT between 0.4-0.6 seconds which corresponds to an 'OK'/orange rating. Additionally, 2 of the 11 (18%) classrooms had a RT greater than 0.6 seconds which is indicated by the "bad"/red rating. Overall, 9 of the 11 (82%) of TRAD rooms in this investigation met the Australian SoundOut App requirements, for acceptable RT.

Evaluating the same group of classrooms using the INTERNATIONAL MEALINGS CLASSIFICATION, showed 2 of the 11 (18%) of the TRAD in this study met the Mealings criteria for a 'good'- 'green' rating for RT which was below 0.4 seconds. A further, 7 of the 11 (64%) had RT between 0.4-0.6 which resulted in an 'OK' or orange rating. Additionally, 2 of the 11 rooms recorded RT in excess of 0.6 seconds which meant they scored a 'Bad' red rating. Overall, 9 of the 11 (82%) of TRAD rooms in this investigation met the International Mealings Classification requirements for acceptable RT.

These results are represented graphically in figure 8

Figure 8: Pie chart showing results of three different rating scales for **Reverberation Time (RT)** in **TRAD**itional classrooms.



7.2 Background Noise Levels

7.2.1 Background Noise Levels (occupied MLE)

Descriptive statistical analysis from the 11 MLE revealed the following. Minimum of 43.4 dBA, Maximum of 69.3 dBA, Mean of 54.3, Standard Deviation of 7.9, Median of 53.6 dBA.

Table 10: The occupied ***Background Noise Levels*** *(**BNL**) recorded in **MLE** classrooms and the recommended levels & ratings by 2 different rating scales NZ MoE, The International (Mealings study), and the Australian Dpt of Education in NSW.*

CLASS (N=11)	NUMBER OF PUPILS	BNL READING (dBA)	**AUSTRALIAN (NSW- Dpt of Ed)** Recommendation GOOD = < 45 dBA OK = 45-50dBA BAD = > 50 dBA	**INTERNATIONAL (MEALINGS)** Recommendation GOOD = < 50 dBA OK = 50-55dBA BAD = > 55 dBA
1	40	64.8	BAD =Red	BAD =Red
2	66	53.6	BAD =Red	OK =Orange
3	70	54.9	BAD =Red	OK =Orange
4	87	52.6	OK =Orange	OK =Orange
5	87	57.4	BAD =Red	BAD =Red
6	89	56.7	BAD =Red	OK =Orange
7	59	46.2	OK =Orange	GOOD =Green
8	54	43.4	GOOD =Green	GOOD =Green
9	45	53.5	BAD =Red	OK =Orange
10	36	69.3	BAD =Red	BAD =Red
11	23	45.0	GOOD =Green	GOOD =Green
Min		43.4		
Max		69.3		
Mean		54.3		
Std. Dev		7.9		
Median		53.6		

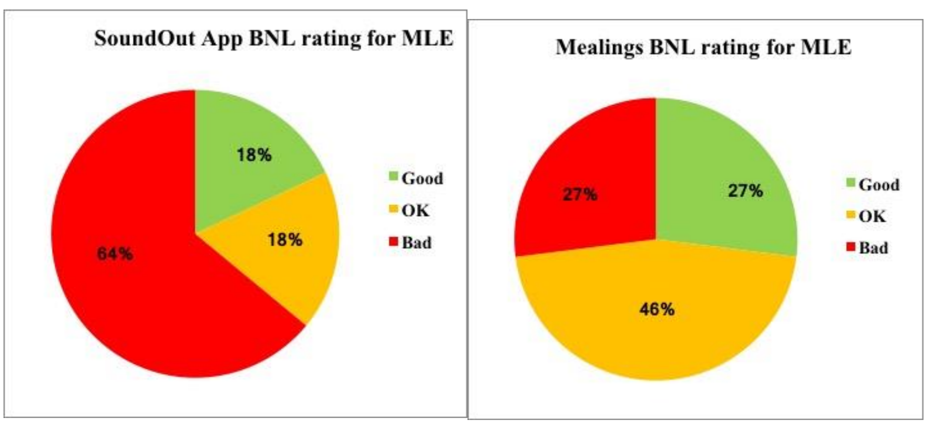
NO specific recommendations are made by the NZ MoE DQLS regarding BNL

The upper limit for acceptable occupied Background Noise Level (BNL) in MLE classrooms recommended by the AUSTRALIAN SOUNDOUT CLASSROOM ACOUSTIC APP, is <50 dBA. Results show, 2 of the 11 (18%) MLE in this study had 'good' green ratings, that is the occupied BNL in the classrooms was below forty five dBA. A further 2 of the 11 (18%) had BNL between 45-50 dBA which corresponds to an 'OK'-Orange rating. Additionally, 7 of the 11 (64%) of MLE classrooms had BNL greater than 50 dBA which is indicated by the "Bad"- Red rating. Overall, 4 of the 11 (36%) MLE in this investigation met the Australian SoundOut App requirements, for acceptable BNL, and 7 (64%) did not.

The upper limit for acceptable occupied Background Noise Level (BNL) in MLE classrooms recommended by the INTERNATIONAL MEALINGS CLASSIFICATION is 55 dBA. This research showed 3 of the 11 (27%) MLE in this study met the Mealings criteria for a 'Good'- 'Green' rating for BNL which was below fifty dBA. Additionally, 5 of the 11 (46%) achieved an 'OK' or orange rating. That is the BNL in the classrooms was between 50-55 dBA. A further 3 of the 11 (27%) MLE recorded BNL in excess of 55 dBA which meant they scored a 'Bad' red rating. Overall, 8 of the 11 (72%) MLE in this investigation met the International Mealings Classification requirements for acceptable BNL.

These results are represented graphically in figure 9

Figure 9: Pie charts showing the results of two different rating scales for **Background Noise Level (BNL)** in **MLE**



7.2.2 Background Noise Levels (occupied TRAD)

Descriptive statistical analysis from the 11 TRAD revealed the following. Minimum of 45.0 dBA, Maximum of 68.7 dBA, Mean of 51.5, Standard Deviation of 7.03, Median of 50.5 dBA.

Table 11: The occupied **Background Noise Levels (BNL)** recorded in **TRAD** classrooms and the levels recommended by the SOUNDOUT CLASSROOM ACOUSTICS

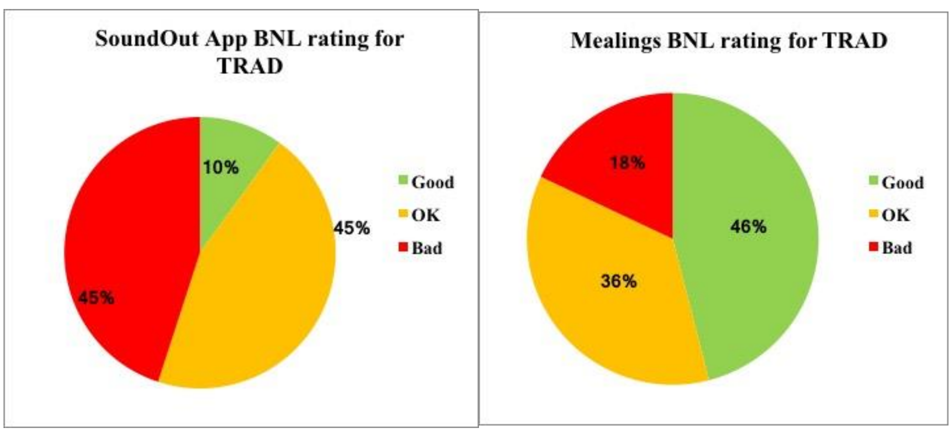
CLASS (N=11)	NUMBER OF PUPILS	BNL READING (dBA)	**AUSTRALIAN (NSW- Dpt of Ed)** Recommendation GOOD = < 45 dBA OK = 45-50dBA BAD = > 50 dBA	**INTERNATIONAL (MEALINGS)** Recommendation GOOD = < 50 dBA OK = 50-55dBA BAD = > 55 dBA
12	30	59	BAD =Red	BAD =Red
13	23	50.5	OK =Orange	OK =Orange
14	22	53.3	BAD =Red	OK =Orange
15	30	68.7	BAD =Red	BAD =Red
16	27	52.8	BAD =Red	OK =Orange
17	28	45	GOOD =Green	GOOD =Green
18	28	47.1	OK =Orange	GOOD =Green
19	30	46.1	OK =Orange	GOOD =Green
20	28	51	BAD =Red	OK =Orange
21	22	45.5	OK =Orange	GOOD =Green
22	24	48.3	OK =Orange	GOOD =Green
Min		45.0		
Max		68.7		
Mean		51.5		
Std. Dev		7.03		
Median		50.5		

NO specific recommendations are made by the NZ MoE DQLS regarding BNL

The upper limit for acceptable occupied Background Noise Level (BNL) in TRAD classrooms recommended by the AUSTRALIAN SOUNDOUT CLASSROOM ACOUSTIC APP, is <50 dBA. Results show, 1 of the 11 (9%) TRAD in this study had ‘good’ green ratings, that is the occupied BNL in the classrooms was below forty-five dBA. A further 5 of the 11 (46%) had BNL between 45-50 dBA which corresponds to an ‘OK’-Orange rating. Additionally, 5 of the 11 (46%) of TRAD classrooms had BNL greater than 50 dBA which is indicated by the “Bad”- Red rating. Overall, 6 of the 11 (55%) TRAD rooms in this investigation met the Australian SoundOut App requirements, for acceptable BNL, and 5 (46%) did not.

The upper limit for acceptable occupied Background Noise Level (BNL) in TRAD classrooms recommended by the INTERNATIONAL MEALINGS CLASSIFICATION is 55 dBA. This research showed 5 of the 11 (46%) TRAD rooms in this study met the Mealings criteria for a 'Good'- 'Green' rating for BNL which was below fifty dBA. Additionally, 4 of the 11 (36%) achieved an 'OK' or orange rating. That is the BNL in the classrooms was between 50-55 dBA. A further 2 of the 11 (18%) TRAD rooms recorded BNL in excess of 55 dBA which meant they scored a 'Bad' red rating. Overall, 9 of the 11 (82%) TRAD in this investigation met the International Mealing Classification requirements for acceptable BNL and 2 (18%) did not. These results are represented graphically in figure 10

Figure 10: Pie Chart showing the results of two different rating scales for **Background Noise Levels (BNL)** in **TRAD**itional classrooms.



7.3 Speech Transmission Index

7.3.1 Speech Transmission Index (MLE)

Descriptive statistical analysis from the 11 MLE revealed the following scores. Minimum of 0.19, Maximum of 0.78, Mean of 0.62, Standard Deviation of 0.16, Median of 0.66.

Table 12: The occupied **Speech Transmission Index** **(STI)** recorded in **MLE** classrooms and the levels recommended by 2 different rating scales. the **Australian (NSW – Dpt of Ed)** SOUNDOUT CLASSROOM ACOUSTICS APP & the **INTERNATIONAL (MEALINGS,2016)**

CLASS (N=11)	STI READING	**AUSTRALIAN (NSW- Dpt of Ed)** Recommendation GOOD = > 0.70 OK = 0.6-0.70 BAD = < 0.6	**INTERNATIONAL (MEALINGS)** Recommendation GOOD = > 0.75 OK = 0.6-0.75 BAD = < 0.6
1	0.57	OK =Orange	BAD =Red
2	0.68	OK =Orange	OK =Orange
3	0.65	OK =Orange	OK =Orange
4	0.73	GOOD =Green	OK =Orange
5	0.56	OK =Orange	BAD =Red
6	0.60	OK =Orange	OK =Orange
7	0.73	GOOD =Green	OK =Orange
8	0.78	GOOD =Green	GOOD =Green
9	0.66	OK =Orange	OK =Orange
10	0.19	BAD =Red	BAD =Red
11	0.70	GOOD =Green	OK =Orange
Min	0.19		
Max	0.78		
Mean	0.62		
Std. Dev	0.16		
Median	0.66		

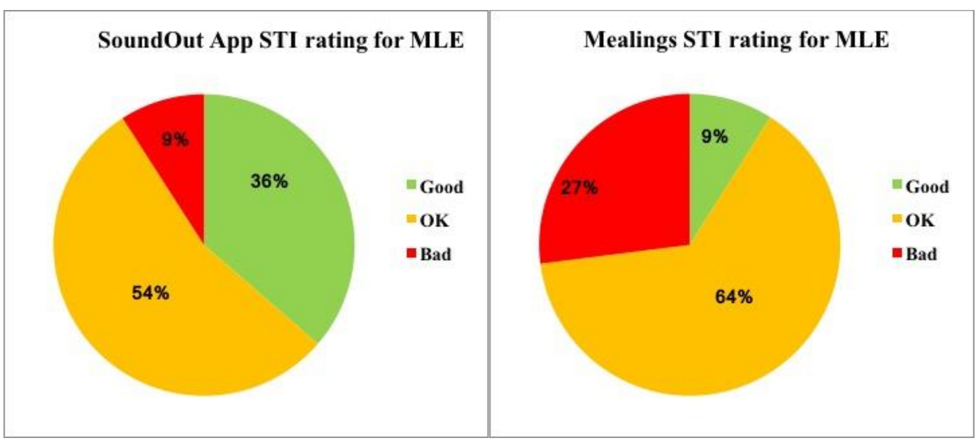
NO specific recommendations are made by the NZ MoE DQLS regarding STI

Acceptable occupied Speech Transmission Index (STI) in MLE classrooms recommended by the AUSTRALIAN SOUNDOUT CLASSROOM ACOUSTIC APP, should be 0.6 or higher. Results show, 4 of the 11 (36%) MLE in this study had ‘good’ green ratings, that is the occupied STI in the classrooms was above 0.7. A further 6 of the 11 (54%) had STI between 0.6-0.7 which corresponds to an ‘OK’-Orange rating. Additionally, 1 of the 11 (9%) of MLE classrooms had STI score below 0.6 which is indicated by the “Bad”- Red rating. Overall, 10 of the 11 (91%) MLE in this investigation met the Australian SoundOut App requirements, for acceptable, and 1 (9%) did not.

Acceptable scores for occupied Speech Transmission Index (STI) in MLE classrooms recommended by the INTERNATIONAL MEALINGS CLASSIFICATION should be 0.6 or higher. This research showed 1 of the 11 (9%) MLE in this study met the Mealings criteria for a 'Good'- 'Green' rating for STI which was greater than 0.6. Additionally, 7 of the 11 (64%) achieved an 'OK' or orange rating. That is the STI score in the classrooms was between 0.6-0.75. A further 3 of the 11 (27%) MLE recorded STI scores < 0.6 which meant they scored a 'Bad'- Red rating. Overall, 8 of the 11 (72%) MLE in this investigation met the International Mealings Classification requirements for acceptable STI scores.

These results are represented graphically in figure 11

Figure 11: Pie chart showing results of two different rating scales for **Speech Transmission Index (STI)** scores in occupied **MLE**.



7.3.2 Speech Transmission Index (TRAD)

Descriptive statistical analysis from the 11 MLE revealed the following scores. Minimum of 0.24, Maximum of 0.72, Mean of 0.61, Standard Deviation of 0.13, Median of 0.66.

Table 13: The **Speech Transmission Index (STI)** scores recorded in **TRAD** classrooms and the levels recommended by 2 different rating scales the **AUSTRALIAN (NSW- Dpt of Ed)** & **INTERNATIONAL (MEALINGS)** SOUNDOUT CLASSROOM ACOUSTICS APP

CLASS (N=11)	STI READING	**AUSTRALIAN (NSW- Dpt of Ed)** Recommendation GOOD = > 0.70 OK = 0.6-0.70 BAD = < 0.6	**INTERNATIONAL (MEALINGS)** Recommendation GOOD = > 0.75 OK = 0.6-0.75 BAD = < 0.6
12	0.51	BAD =Red	BAD =Red
13	0.62	OK =Orange	OK =Orange
14	0.63	OK =Orange	OK =Orange
15	0.24	BAD =Red	BAD =Red
16	0.66	OK =Orange	OK =Orange
17	0.72	GOOD =Green	OK =Orange
18	0.66	OK =Orange	OK =Orange
19	0.69	OK =Orange	OK =Orange
20	0.64	OK =Orange	OK =Orange
21	0.67	OK =Orange	OK =Orange
22	0.68	OK =Orange	OK =Orange
Min	0.24		
Max	0.72		
Mean	0.61		
Std. Dev	0.13		
Median	0.66		

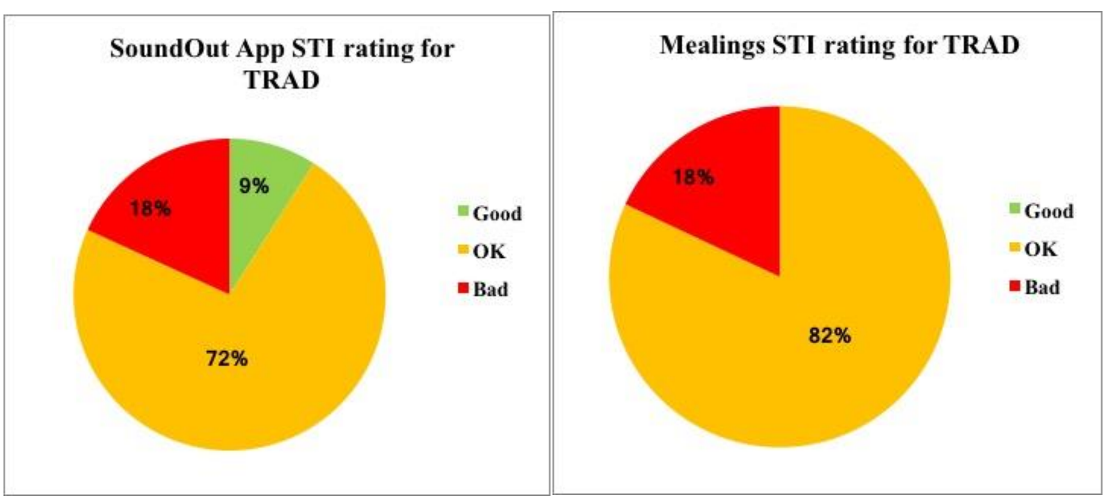
NO specific recommendations are made by the NZ MoE DQLS regarding STI

Acceptable scores for occupied Speech Transmission Index (STI) in TRAD classrooms recommended by the AUSTRALIAN SOUNDOUT CLASSROOM ACOUSTIC APP, should be 0.6 or higher. Results show, 1 of the 11 (9%) TRAD in this study had ‘good’ green ratings, that is the occupied STI score in the classrooms was above 0.7. A further 8 of the 11 (72%) had STI between 0.6-0.7 which corresponds to an ‘OK’-Orange rating. Additionally, 2 of the 11 (18%) of TRAD classrooms had STI scores below 0.6 which is indicated by the “Bad”- Red rating. Overall, 9 of the 11 (91%) TRAD in this investigation met the Australian SoundOut App requirements, for acceptable STI scores, and 2 (18%) did not.

Acceptable scores for occupied Speech Transmission Index (STI) in TRAD classrooms recommended by the INTERNATIONAL MEALINGS CLASSIFICATION should be 0.6 or higher. This research showed none of the 11 (0%) TRAD in this study met the Mealings criteria for a ‘Good’- ‘Green’ rating for STI which required a score greater than 0.75. Additionally, 9 of the 11 (81%) achieved an ‘OK’-Orange rating. That is the STI score in the classrooms was between 0.6-0.75. A further 2 of the 11 (18%) TRAD rooms recorded STI scores < 0.6 which meant they scored a ‘Bad’- Red rating. Overall, 9 of the 11 (81%) TRAD rooms in this investigation met the International Mealings Classification requirements for acceptable STI scores, and 2 did not.

These results are represented graphically in figure 12

Figure 12: Pie chart showing the results of two different rating scales for **Speech Transmission Index (STI)** scores in occupied **TRAD**itional classrooms



7.4 Comparison of MLE & TRAD acoustics across all four measures

Q1, Hypothesis A

H_0 Acoustic measurements for Traditional classrooms (TRAD) will not be significantly different to modern learning environments (MLE) over a range of parameters specifically: "ANL", "BNL", "RT" and "STI" (Ambient Noise Level/Background Noise Level/Reverberation Time/Speech Transmission Index).

Descriptive statistics revealed the presence of skewness and kurtosis across all the acoustic parameters under consideration, (see figure 13), to accommodate this, nonparametric tests were used.

A Mann Whitney test showed the null hypothesis was supported as there was no significant difference found between the two types of classroom across the parameters tested (ANL, RT, BNL, STI)

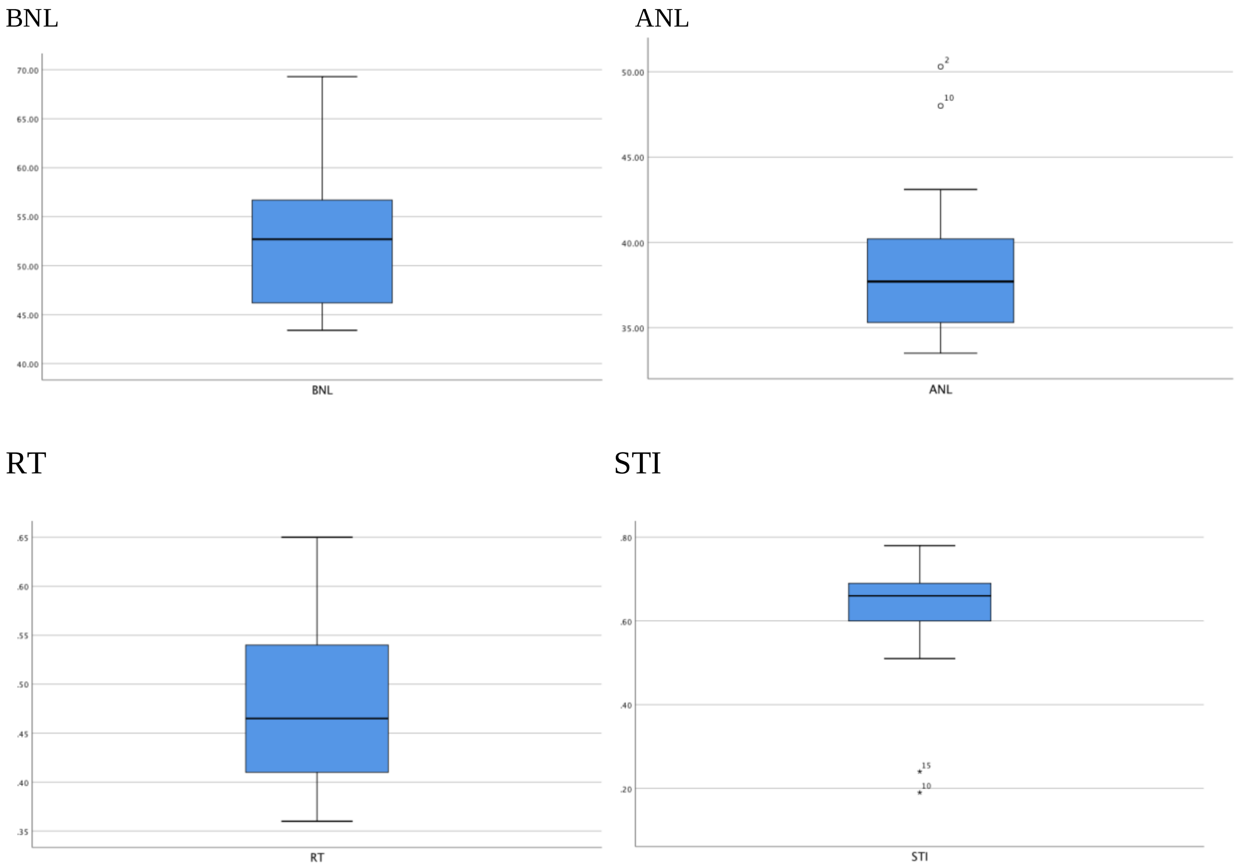
For <u>BNL</u>, MLE scores *(M=54.31, SD=7.91)* were not significantly different from TRAD scores *(M=51.57, SD=7.04) (U =* 44.50, *N=22, p=.31, d=.37, pwr = .43)*

For <u>ANL</u>, MLE scores *(M=40.20, SD=5.21)* were not significantly different from TRAD scores *(M =37.05, SD=2.71) (U =*38.00, *p=.15 d=.76, pwr=.59)*

For <u>RT</u>, MLE scores *(M=.46, SD=.08)* were not significantly different from TRAD scores *(M =.49, SD=.08) (U =*43.50, *p=.28, d=.76, pwr=.73)*

For <u>STI</u>, MLE scores *(M=.62, SD=.16)* were not significantly different from TRAD scores *(M =.61, SD=.13) (U =*52.50, *p=.62, d=.76, pwr=.89)*

Figure 13: Box plots showing distribution for BNL, ANL, RT & STI



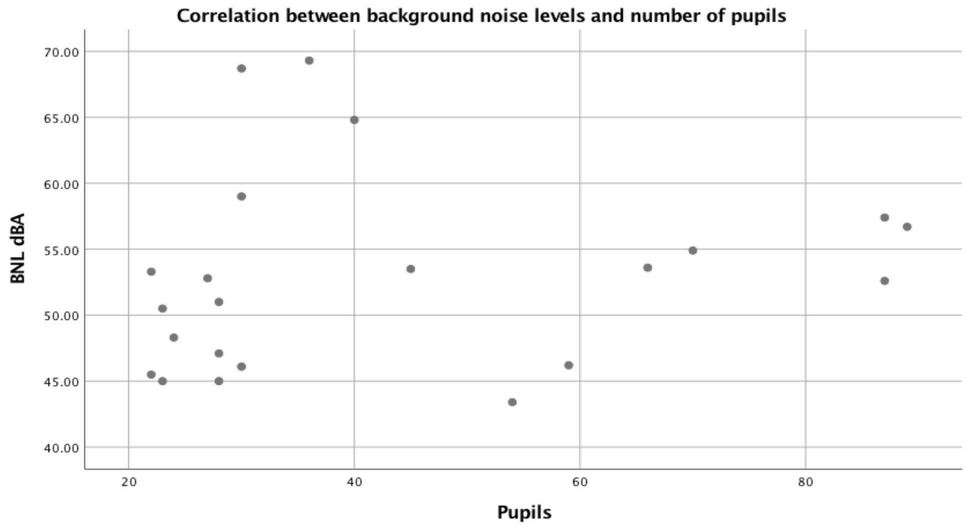
7.5 BNL and number of children in a classroom

Q2 Is there a relationship between the number of pupils in a classroom, and the levels of background noise?

<u>**Hypothesis B**</u> **=** H_0 There will be no significant correlation between the number of children in a class and the occupied background noise levels (BNL).

Non-parametric Spearman's correlation analysis showed the null hypothesis was supported at the 0.025 level (two-tailed) *(p = .06):* r_s (22) = .40): r_s^2= .02) However, a significant correlation was detected at the 0.05 level *(1-tailed) (p = .03):* r_s (22) = .40): r_s^2= .02). Which indicates there is a significant correlation between the number of children in a class and the level of background noise.

Figure 14: Scatterplot showing the correlation between **Background Noise Level (BNL)** & number of pupils in a room.



7.6 MLE & TRAD acoustics for younger versus older children

Q3 Are the different acoustic needs of younger children reflected in their classrooms?

Hypothesis C = H_0 There is no significant difference in any of the acoustic parameters ("ANL", "BNL", "RT" and "STI") for younger or older age groups

A Kruskal-Wallis test showed the null hypothesis was supported.

BNL were not significantly different between the younger group (M=55.74, SD=8.26, n=11) compared to the older group (M=50.15, SD= 5.55, n=11) (*H* = 2.81, p=.10, d=.79, pwr=.54)

ANL were not significantly different between the younger group (M=4.44, SD=5.10, n=11) the older group (M=36.81, SD= 2.60, n=11) (*H* = 3.51, p=0.06, d=.89, pwr=.53)

RT were not significantly different between the younger group (M=.50, SD=0.10, n=11) the older group (M=.45, SD= .06, n=11) (*H* = 1.48, p=.24, d=.55, pwr=.52)

STI were not significantly different between the younger group (M=.57, SD=.18, n=11) and the older group (M=.66, SD= .08, n=11) (*H* = 1.65, p=.21, d=.66, pwr=.61)

7.7 Classrooms for hearing impaired children

Q4 Are children in NZ with identified hearing/language impairments being taught in classrooms with acoustic which accommodate their hearing and listening needs?

Hypothesis D = H_0 There will be no significant difference in any of the acoustic parameters found in classrooms where children with identified hearing/language impairments are taught.

No statistical analysis was conducted for this question due to low numbers of children in the study who had an identified hearing loss. Four were being schooled in a traditional setting, and one was in a modern learning environment.

7.8 Number of recommendations met by MLE & TRAD

Q5 When “ANL” “BNL” “RT” and “STI” are considered altogether, do MLE or TRAD rooms meet “overall” recommendations specified in the Australian, or International scales. (ambient noise level/background noise level/reverberation time/speech transmission index).

No statistical analysis was undertaken in relation to this question, as it was essentially an evaluation based on the scales from the rating classifications used in this project.

Note, the DQLS does not currently include recommendations on BNL and STI, so just the two recommendations for ANL and RT are reported in the first overall comparison between MLE and TRAD rooms.

7.8.1 NZ Ministry of Education (DQLS)

Table 14: Overall acoustic performance of **MLE** Classrooms using the
NZ MoE DQLS Rating

CLASS	BNL (dBA)	ANL (dBA) GOOD = < 35 dBA OK = 35-45 dBA BAD = > 45 dBA	RT (s) GOOD = < 0.50 sec OK = 0.5-0.8 sec BAD = > 0.80 sec	STI
1		42.9	0.50	
2		50.3	0.42	
3		37.8	0.41	
4		38.9	0.39	
5		41.4	0.43	
6		40.0	0.42	
7		37.8	0.41	
8		34.5	0.46	
9		37.1	0.36	
10		48.0	0.65	
11		33.5	0.56	

NO specific recommendations are made by the NZ MoE DQLS regarding BNL, or STI

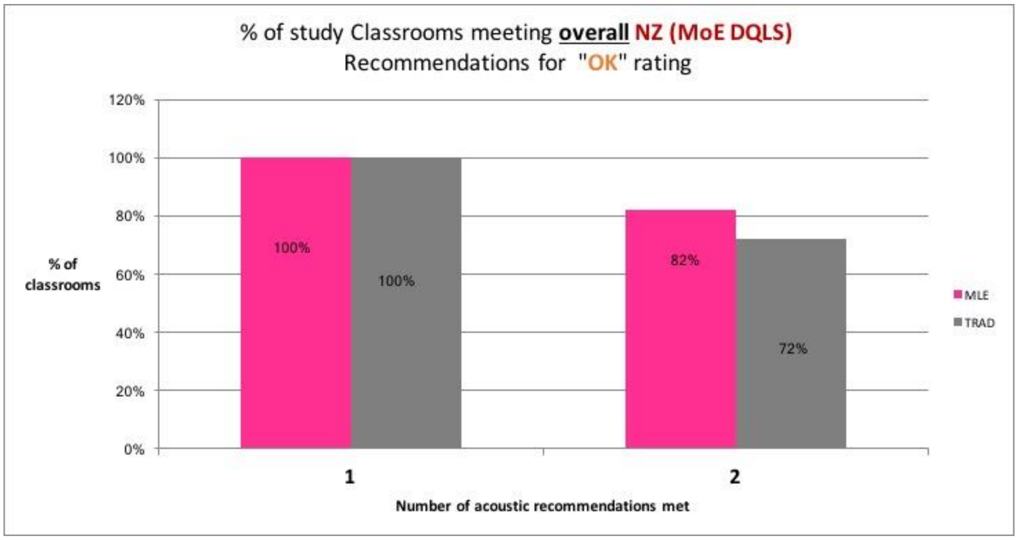
Table 15: Overall acoustic performance of **TRAD** Classrooms using the
NZ MoE DQLS Rating

CLASS	BNL (dBA)	ANL (dBA) GOOD = < 35 dBA OK = 35-45 dBA BAD = > 45 dBA	RT (s) GOOD = < 0.40 sec OK = 0.4-0.5 sec BAD = > 0.50 sec	STI
12		38.2	0.50	
13		40.2	0.60	
14		34.7	0.62	
15		43.1	0.48	
16		37.6	0.47	
17		37.6	0.47	
18		34.4	0.40	
19		34.6	0.41	
20		35.3	0.50	
21		35.3	0.56	
22		36.5	0.39	

NO specific recommendations are made by the NZ MoE DQLS regarding BNL, or STI

These results are represented graphically in figure 15

Figure 15: Percentage of study classrooms meeting overall NZ **MoE DQLS** recommendations for **"OK"** rating



Using the **NZ MoE DQLS** as the rating scale, 11 of the 11 (100%) MLE, and 11 of the 11 (100%) TRAD classrooms met at least one of the recommended acoustic parameters, either ANL, (<45dB LAeq) or RT (MLE=0.4-0.8s/TRAD=<0.5s) Additionally, 9 of the 11 (82%) MLE, and 8 of the 11 (72%) TRAD classrooms met both of the recommended ANL and RT.

In total, combining, both MLE and TRAD rooms, 17 of the 22 (77%) rooms surveyed in this study met the current DQLS 2016 recommendations

7.8.2 Australian (Department of Education-NSW)

Table 16: Overall acoustic performance of **MLE** Classrooms using the **AUSTRALIAN (NSW, Dpt of Ed)** Rating

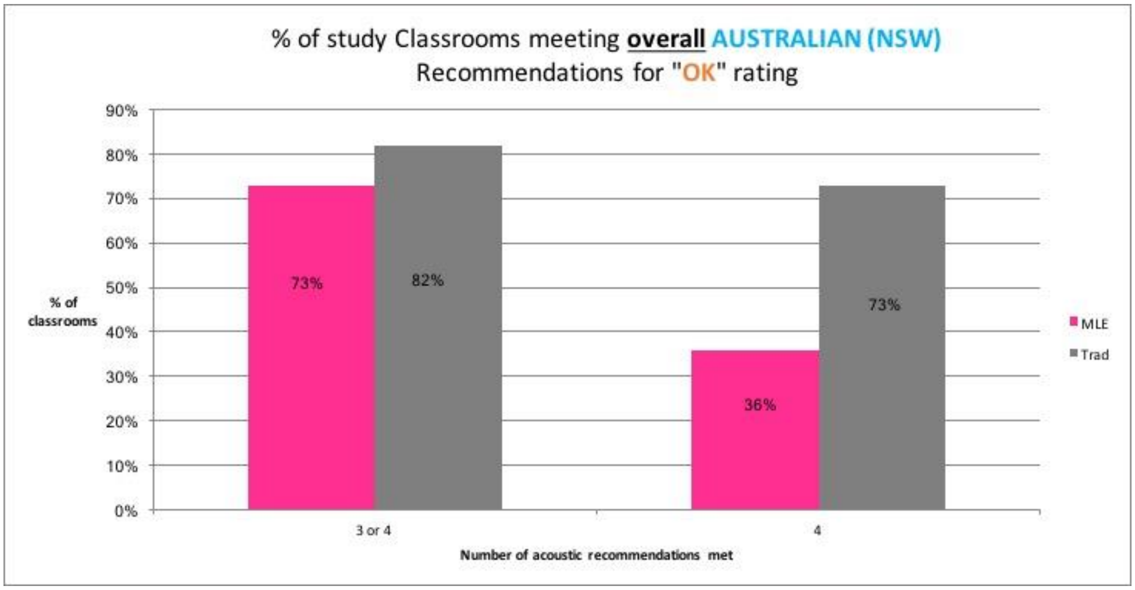
CLASS	BNL (dBA) GOOD=< 45 dBA OK =45-50dBA BAD => 50 dBA	ANL (dBA) GOOD=< 40 dBA OK =40-45dBA BAD => 45 dBA	RT (sec) GOOD= < 0.40s OK = 0.4-0.6s BAD = > 0.60s	STI GOOD = > 0.70 OK = 0.6-0.70 BAD = < 0.6
1	64.8	42.9	0.50	0.57
2	53.6	50.3	0.42	0.68
3	54.9	37.8	0.41	0.65
4	52.6	38.9	0.39	0.73
5	57.4	41.4	0.43	0.56
6	56.7	40.0	0.42	0.60
7	46.2	37.8	0.41	0.73
8	43.4	34.5	0.46	0.78
9	53.5	37.1	0.36	0.66
10	69.3	48.0	0.65	0.19
11	45.0	33.5	0.56	0.70

Table 17: Overall acoustic performance of **TRAD** Classrooms using the **AUSTRALIAN (NSW, Dpt of Ed)** Rating

CLASS	BNL (dBA) GOOD=< 45 dBA OK =45-50dBA BAD => 50 dBA	ANL (dBA) GOOD=< 40 dBA OK =40-45dBA BAD => 45 dBA	RT (s) GOOD= < 0.40s OK = 0.4-0.6s BAD = > 0.60s	STI GOOD = > 0.70 OK = 0.6-0.7 BAD = < 0.6
12	59.0	38.2	0.50	0.51
13	50.5	40.2	0.60	0.62
14	53.3	34.7	0.62	0.63
15	68.7	43.1	0.48	0.24
16	52.8	37.6	0.47	0.66
17	45.0	37.6	0.47	0.72
18	47.1	34.4	0.40	0.66
19	46.1	34.6	0.41	0.69
20	51.0	35.3	0.50	0.64
21	45.5	35.3	0.56	0.67
22	48.3	36.5	0.39	0.68

These results are represented graphically in figure 16

Figure 16: Percentage of study classrooms meeting overall
AUSTRALIAN (NSW Dpt of Ed,) recommendations for **"OK"** rating



Using the **AUSTRALIAN (NSW Dpt of Ed)** as the rating scale, and a measurement grading of **"OK"** 8 of the 11 (73%) MLE, and 9 of the 11 (82%) TRAD classrooms met 3 or 4 of the recommended acoustic parameters, namely ANL, (<45dB LAeq) RT (MLE=0.4-0.8s/ TRAD=<0.5s) BNL(=45-50dBA) and STI(= 0.6-0.7) Additionally, 4 of the 11 (36%) MLE, and 8 of the 11 (73%) TRAD classrooms met all 4 of the recommended acoustic parameters including ANL, RT, BNL and STI.

In total, combining, both MLE and TRAD rooms, 17 of the 22 (77%) rooms surveyed in this study met the current 3 or 4 of the **AUSTRALIAN (NSW Dpt of Ed)** recommendations. While 12 of the 22 (55%) rooms surveyed in this study met all 4 of the **AUSTRALIAN (NSW Dpt of Ed)** recommendations.

7.8.3 International (Mealings, 2016)

Table 18: Overall acoustic performance of **MLE** Classrooms using the **INTERNATIONAL (MEALINGS)** Rating

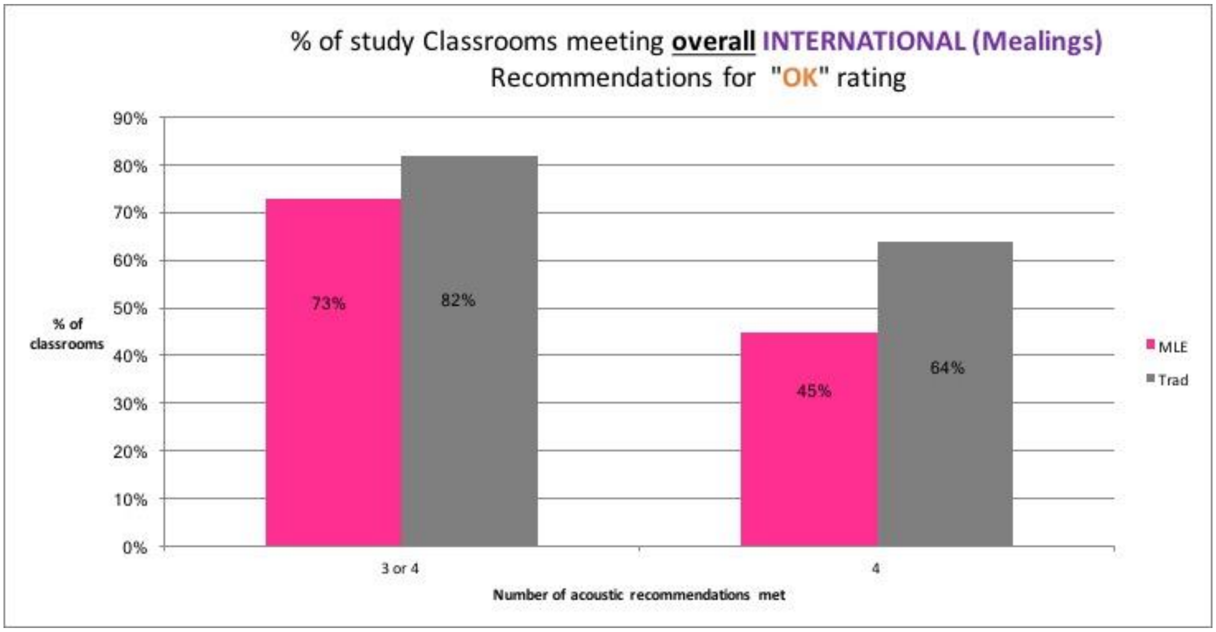
CLASS	BNL (dBA) GOOD=< 50 dBA OK = 50-55dBA BAD = > 55 dBA	ANL (dBA) GOOD= < 30 dBA OK = 30-40dBA BAD = > 40 dBA	RT (sec) GOOD =< 0.40 s OK =0.40-.6 s BAD = > 0.60 s	STI GOOD= > 0.75 OK =0.6-.75 BAD = < 0.6
1	64.8	42.9	0.50	0.57
2	53.6	50.3	0.42	0.68
3	54.9	37.8	0.41	0.65
4	52.6	38.9	0.39	0.73
5	57.4	41.4	0.43	0.56
6	56.7	40.0	0.42	0.60
7	46.2	37.8	0.41	0.73
8	43.4	34.5	0.46	0.78
9	53.5	37.1	0.36	0.66
10	69.3	48.0	0.65	0.19
11	45.0	33.5	0.56	0.70

Table 19: Overall acoustic performance of **TRAD** Classrooms using the **INTERNATIONAL (MEALINGS)** Rating

CLASS	BNL (dBA) GOOD= < 50 dBA OK = 50-55dBA BAD = > 55 dBA	ANL (dBA) GOOD= < 30 dBA OK = 30-40dBA BAD = > 40 dBA	RT (s) GOOD =< 0.40 s OK =0.40-.6 s BAD = > 0.60 s	STI GOOD= > 0.75 OK = 0.6-.75 BAD = < 0.6
12	59.0	38.2	0.50	0.51
13	50.5	40.2	0.60	0.62
14	53.3	34.7	0.62	0.63
15	68.7	43.1	0.48	0.24
16	52.8	37.6	0.47	0.66
17	45.0	37.6	0.47	0.72
18	47.1	34.4	0.40	0.66
19	46.1	34.6	0.41	0.69
20	51.0	35.3	0.50	0.64
21	45.5	35.3	0.56	0.67
22	48.3	36.5	0.39	0.68

These results are represented graphically in figure 17

Figure 17: Percentage of study classrooms meeting overall
INTERNATIONAL (MEALINGS) recommendations for **“OK”** rating



Using the **INTERNATIONAL (MEALINGS)** as the rating scale, and a measurement grading of **“OK”** 8 of the 11 (73%) MLE, and 9 of the 11 (82%) TRAD classrooms met 3 or 4 of the recommended acoustic parameters namely ANL, (<45dB LAeq) RT (MLE=0.4-0.8s/ TRAD=<0.5s) BNL(= 50-55dBA) and STI(= 0.6-.75) Additionally, 5 of the 11 (45%) MLE, and 7 of the 11 (64%) TRAD classrooms met all 4 of the recommended acoustic parameters including ANL, RT, BNL and STI.

In total, combining, both MLE and TRAD rooms, 17 of the 22 (77%) rooms surveyed in this study met the current 3 or 4 of the **INTERNATIONAL (MEALINGS)** recommendations. While 12 of the 22 (55%) rooms surveyed in this study met all 4 of the **INTERNATIONAL (MEALINGS)** recommendations.

DISCUSSION

The overarching goal of this thesis was to explore the acoustics of two different styles of classrooms currently found in the NZ primary school system, namely traditional and modern learning environments in order to evaluate their suitability as venues in which to educate children This study was essentially a scoping study, to investigate how a set of common acoustic measurements taken in NZ classrooms compared to guidelines suggested by the NZ MoE, the Australian Dept. of Ed in NSW, and current International research (Mealing, 2016). The intention was to compare Traditional cellular rooms, (TRAD) and the Modern Learning Environments (MLE), to discern whether these two different styles of classroom differed significantly from each other across a series of acoustic measurements. The parameters under consideration were the, Ambient Noise Level (ANL), the Reverberation Time (RT), Background Noise Levels (BNL), and the Speech Transmission Index scores (STI). The first two measures (ANL, RT) are taken when the rooms are unoccupied, and the second two (BNL, STI) are taken when the room is occupied with students. The current NZ guidelines like many others worldwide only consider the two unoccupied measures: ANL and RT. There is mounting evidence that an examination of the acoustic performance of a room when it is occupied provides a better overall picture of the acoustic health of a teaching space (Caning & James, 2012; Greenland & Shield, 2011; Mealing, Demouth, Bucholz & Dillon, 2015; Mealing, 2016; Wilson et al, 2018)

The following discussion endeavours to consider the results in regard to the three different classroom acoustic guidelines, with a view to exploring how a sample of MLE and TRAD NZ classrooms rated. These results were analysed in light of the current literature to ascertain whether there are any practical implications for the teaching spaces where children are expected to listen and learn in. Research question one was interested in measuring four different acoustic parameters in order to proceed to answer the remaining research questions and their accompanying hypotheses (A, B, C, D). Each hypothesis was examined individually, in the context of the relevant literature. The last part of the discussion will pertain to research question five, concerning the overall acoustic performance when all four test measures are considered together.

Hypothesis A mooted that scores for traditional classrooms (TRAD) would be not significantly different to modern learning environments (MLE) over a range of acoustic parameters which included: ANL, RT, BNL, STI, (Ambient Noise Level, Reverberation Time, Background Noise Level, Speech Transmission Index scores). Statistical analysis showed the null hypothesis was supported. Allied to this testing, was the opportunity to rate the two different types of classrooms against recommendations from NZ, Australian, and International bodies.

AMBIENT NOISE LEVEL (ANL)

The first research question asked what typical Ambient Noise Levels (ANL) were in both TRAD and MLE classrooms, and how the results rated against NZ, Australian, and International recommendations. The NZ MoE requirement suggests that ambient noise levels in unoccupied classrooms be kept below 45 dBA. Out of the twenty two classrooms which were assessed in this study, twenty were found to comply with the NZ MoE guidelines. Specifically, nine (82%) MLE and all eleven (100%) TRAD classrooms, would be deemed to have suitable ANL to teach children in. Considering these same classrooms under the Australian Dpt of Education rating scale the overall results for both MLE and TRAD rooms were identical, although the distribution between ‘good’-green and ‘OK’-orange varied as any reading less than 40dBA qualified as ‘good’-green under the Australian rating while ‘good’-green was any measurement below 35 dBA under the NZ recommendations. The International classification requirements from the Mealing study found that only seven (64%) of the MLE, and nine (82%) of the TRAD rooms met the criteria for suitable ambient noise levels. Under this rating system, none of the MLE or TRAD rooms could be classified as being ‘good’-green environments in terms of the ambient noise levels recorded. The International Mealings classification stipulates ANL ought to be below 30 dBA to be considered ‘good’ on this acoustic parameter.

The difference in ANL between MLE and TRAD was not statistically significant, this may be partly due to the reduced power of this scoping investigation which only examined 22 teaching spaces. Furthermore, the “degree of openness” in the MLE was not specifically controlled for. Firstly, a) totally open-plan building with portable furniture separating teaching spaces. Secondly, b) semi open-plan in which some large structural walls are present, but no doors divide the teaching spaces. Thirdly, c) open-plan spaces which can be readily closed off through sliding doors etc. These differences may have influenced the ANL results recorded in this project. However, more of the TRAD rooms did meet acceptable levels using all three different rating scales. This could possibly be explained by the sheer reduction in the number and variety of equipment within a single room compared to the larger space of the MLE. A TRAD room for example typically only had one heat pump, where a MLE frequently had multiple units. One MLE even had a photocopier operating within the main teaching space.

Frequently ANL are considered important due to the impact they may have on children’s ability to hear well with the classroom, but an equally salient reason is the potential negative effect ANL can have on teacher’s vocal health (Shield & Dance, 2014). A recent study demonstrated a positive correlation between ANL and voice strain amongst a cohort of teachers. (Durup, Shield, Dance, Sullivan, & Gomez-Agustina, 2015). At least fifty percent of the participants had average voice levels which could be classified as either, raised/loud/very loud as defined by the BS ISO 9921-1) (Durup et al., 2015). Those findings agree with a UK survey of 127 teachers in which sixty five percent acknowledged having to raise their voice numerous time during the day. Seventeen percent felt they were frequently shouting, and fifty percent said they had to speak louder to be heard above others talking or noise from equipment (Shield & Dance, 2014). That same study concluded that vocal problems were perceived as a substantial occupational risk for teachers, subsequently, most participants (94%) felt vocal coaching and management ought to be part of the teacher training curriculum.

While the current study did not find statistically significant differences in either the ANL or BNL between MLE or TRAD classrooms, teachers also report difficulties with background noise. The current study yielded a slight correlation between BNL, and the number of children in MLE spaces. Other research has been able to demonstrate increased levels of noise pertaining to MLE environments (Mackenzie & Airy, 1999; Mealings 2015; Shield & Dockrell, 2003; Shield et al, 2010; Walsh, 1975).

Another investigation which reported positive outcomes from management of noise levels including ANL was the 2012 Essex study. It was authored by Canning and James, and involved a series of successive acoustic improvements to classrooms until they reached the optimal sound environment required by the British Association of Teachers of the Deaf. Teaching staff using the facilities reported they could talk to their classes at normal levels without having to raise their voice, along with lower levels of stress (Canning, 2012).

These findings are in accordance with the literature which suggests that the containment of ANL is more easily managed in TRAD cellular classrooms as they prevent the ingress of sound from adjacent areas/rooms which is not as achievable in MLE (Mealings, 2015, Shield, Greenland & Dockrell, 2010)

REVERBERATION TIME (RT)

The second element of question one asked what typical Reverberation Times (RT) were in both TRAD and MLE classrooms, and how the results rated against NZ, Australian, and International recommendations. The NZ MoE requirement suggests that RT in unoccupied TRAD classrooms should be between 0.4-0.5, and 0.5-0.8 seconds for MLE (dependent upon room volume, - (see MoE DQLS 2016 v2 pg 13). Out of the twenty two classrooms which were assessed in this study, nineteen were found to comply with the NZ MoE guidelines. Specifically, all eleven (100%) MLE and eight (72%) TRAD classrooms, would be deemed to have suitable RT to teach children in. Both the Australian Dpt of Education, and the International Mealings rating scale classifies a RT of 0.4-0.6 seconds as suitable to teach children in. A ‘good’-green rating was achieved by two (18%) MLE who had RT of less than 0.4 seconds, while one (9%) MLE was rated as ‘Bad’-Red as it had a RT over 0.6 seconds.

The TRAD classrooms in this study had slightly poorer results across all three rating scales (NZ/Australia/International). The NZ MoE DQLS has slightly tighter recommendation, as it suggests RT should be between 0.4-0.5 in TRAD rooms whereas the Australian Dpt of Ed, and the International Mealings criteria allow for a RT between 0.4-0.6 seconds. This slight difference resulted in three (27%) of TRAD rooms not being classified as having suitable RT times under the NZ DQLS recommendation where only two (18%) of rooms did not meet the standard under the Australian and International scales. The remainder of the rooms were rated as ‘good’-green rooms as the RT was below 0.4 seconds. Six (55%) rooms were classified as ‘OK’-

orange under the NZ DQLS, while the Australian and International scales rated seven (64%) rooms as having ‘OK’-Orange classification with an RT between 0.4-0.6 seconds.

The difference in RT between MLE and TRAD was not statistically significant, even though the MLE in this study outperformed the TRAD rooms by achieving a greater number with suitably low RT times across all three scales. These results did come as a surprise to the researcher who was anticipating the RT might be poorer in MLE. Again, this may in part be due to the reduced power of this scoping investigation which only examined 22 teaching spaces. Furthermore, the MLE in this study had been either built, or converted within the preceding five years, hence it is more likely they were fitted with modern, acoustic panelling which has high sound absorption coefficients on all available surfaces (ceiling/walls). This was true of new purpose-built MLE, or those MLE created in older, buildings with solid concrete footings. This may be pure co-incidence, or it may be due to the use of acoustic engineers in the design phase, or it may be due to an awareness that the MoE DQLS was to be re-versioned with stricter requirements on RT times?

As a consequence of the earthquakes and the enormous number of new or re-furbished classrooms, in Christchurch, the data in this study must be viewed with caution, as other MLE around the country may not yield similar reverberation times. What is also unknown, is whether any unintentional selection bias occurred? Even although the schools were randomly selected, it is still possible to conceive that the Principals who did offer their classrooms for testing were confident in the acoustic design of those spaces, while those who were not, abdicated from participating in this study? The use of acoustic consultants is endorsed by both the literature and the MoE DQLS v2 if classrooms are to be acoustically suitable for children to hear well in (Ramma, 2015; Mealings, et al, 2015; Whitlock, 2016). Information regarding the use of specialist acoustic consultants was requested, but not always provided by the schools in this study. This may be a further design weakness which ought to have been controlled for.

The MLE which performed poorest were those which were essentially older pre-fab style buildings which had largely been converted to MLE by “removing” adjoining doors, with little other acoustic modifications. These spaces tended to have older less effective ceiling tiles, and minimal absorptive material on the walls. This increased presence of harder reflective surfaces is likely to have contributed to the elevated RT scores found in these MLE. This difference was noted at the time of the recordings, but not tightly controlled for which quite possibly contributed to some of the skewness within the data set.

The NZ MoE DQLS document makes allowances for the enormous potential variety of MLE designs by signalling that RT in these spaces is contingent upon the volume of the space under consideration. (See pg. 13 DQLS for details.) This has the effect of increasing the length of RT which is deemed ‘acceptable’ under the DQLS acoustic guidelines. A measurement between 0.5-0.8 seconds is acceptable, provided this sits within the afore mentioned room volume requirements. It was not anticipated that 82 % of the MLE in this study would have RT which were better than the NZ MoE requirement. The other two scales (Australian, NSW Dpt of ED, International Mealings) do not differentiate between the style of teaching space, (MLE OR TRAD) but rather they recommend RT should be between 0.4-0.6 seconds to minimise unwanted reflections which have the potential to interfere with how well a desired signal will be heard. This is consistent with much of the literature (Wrobelewski et al, 2012). It may be that architects and acoustic engineers are designing to other more general building codes such as the AS/NZ 2107:2000 which require the RT to be better than that specified by the NZ MoE DQLS. This may be an alternative explanation for the extremely good RT scores 90% were acceptable using the stricter rating criteria found in the Australian and International scales.

The TRAD rooms did not perform quite as well on measures of RT across all three different rating scales. The NZ MoE DQLS specifies TRAD rooms ought to have RT between 0.4-0.5 seconds while the other two scales suggest 0-4-0.6 seconds is acceptable. Presumably this is due to the considerable uniformity of design found in more traditional classrooms. Under the stricter NZ MoE DQLS scale, 72% of TRAD rooms had acceptable RT, while the other two scales suggested 82 % of the TRAD rooms in the study had suitable RT. There was a mixture of acoustic treatment in the form of ceiling/wall panels present in these rooms. A few had modern materials, but the majority appeared to have older less absorptive panels. (see appendix). It is worth noting that in all likelihood when these rooms were built, they were designed to utilise the early reflections in the rooms to ensure the teacher's voice carried from the front to the back of the room (Bradley, Sato & Picard, 2003). Since the "stand-and-deliver' pedagogical style of teaching from the front of the classroom is no longer in vogue, it is likely the RT results from these TRAD buildings reflect the period in which they were built. It is quite conceivable that with the addition of suitable modern acoustic wall and particularly ceiling tiles the RT in these rooms could very easily be brought up to specifications recommended by all three rating scales used in this study.

<u>BACKGROUND NOISE LEVEL</u>

The NZ MoE DQLS offers no specific recommendations regarding Background Noise Levels in classrooms. Hence the BNL measurements in this discussion only include the criteria and rating scales from The Australian Dpt of Ed (NSW) and International (Mealing, 2016 study).

During the analysis of the all the acoustic parameters, the most stringent recommendations consistently occurred in the International scale, with one exception; BNL. On this one measure, the International scale was not the toughest. It is conceivable that this noticeable aberration may be because the NSW Dpt of Ed considers that BNL is largely a consequence of teacher management rather than classroom environment?

Results from this testing were consistent with the expectation that higher background noise levels were more likely to occur in MLE environments than TRAD classrooms. It was anticipated that this would be a consequence of the greater numbers of children present in the MLE. However, in this study, no statistically significant difference was found between the levels of background noise recorded in the two different types of teaching space. This is inconsistent with previous research which has demonstrated higher levels of BNL occur in MLE (Finitzo-Hieber et al, 1988; Mackenzie & Airy, 1999; Mealings 2015; Shield & Dockrell, 2003; Shield et al, 2010; Walsh, 1975).

There may be several reasons for this unexpected finding. To begin with, the presence of the researcher in the room could have influenced both student and teacher behaviour. There exists the possibility that students may have been quieter than normal, perhaps hoping to please their teacher, and perhaps teacher's in turn may have instigated tighter controls on noise levels endeavouring to appear to have good classroom management? Attempts were made to mitigate any impact of the researcher being present in the space, including having the children engaged in an independent activity rather than a group activity; as it was easier to have more standardised behaviour during reading/writing or in the case of younger children colouring in. Also, the result was an average of three separate readings which were taken at three different times from three different points in the room.

While the mean for the **MLE** was 54.3 dBA, and it was 51.5 dBA in TRAD rooms, what is interesting is how differently each of the two rating scales classified the results. The Australian scale meant only 4 (36%) of the 11 MLE in this study had acceptable BNL, contrast this with the International scale which rated the same set of data but classified 8 (72%) of the MLE had suitable BNL. It seems plausible that at least some of the disparity in the outcomes of these classifications is due to the different expectations around BNL held by the two bodies. It may be that the Australian Dpt of Ed considers BNL are able to be kept at lower levels by the teacher than what the International research is indicating, hence the disparity in outcomes. This possibility is important as background noise is one of the chief complaints made by teachers about this style of teaching space. Chiefly because it causes them to raise their voice which induces vocal difficulties for many in the profession (Pelegrín-García, Brunskog, & Rasmussen, 2014; Sapienza, Crandell, & Curtis, 1999; Shield & Dance, 2014) (Kristiansen et al., 2016) Additionally, it is also one of the concerns frequently voiced by parents about MLE (Gerritson, 2015)

A closer examination of these findings may shed some light on likely different perspective each party has on background noise levels in teaching spaces. The Australian NSW Dpt of Ed recommended, 45dBA to achieve a “Good”-green rating which 2 MLE (18%) scored. An “OK”-orange ranking required the BNL to be between 45-50 dBA which a further 2 MLE (18%) achieved. While a “Bad”-Red rating was awarded when the BNL were 50 dBA or more which was the case for 7 (64%) of the MLE in this investigation (see Figure 9). Combining both the green and orange rated scores meant just 4 (36%) of MLE were operating within the BNL tolerances recommended by the Australian Dpt of Ed. Re-classifying these same BNL levels using the rating criteria from International research which was outlined in the 2016 Mealings study yields a contrasting result. To achieve a ‘Good”-green classification, BNL needed to be < 50 dBA which occurred in 3 (27%) of MLE. An “OK”- orange rating was awarded to 5 (46%) of the open plan teaching spaces under investigation. A number of MLE 3 (27%) in total yielded BNL in excess of 55 dBA which meant these rooms were accorded a “Bad”-red rating. Overall this meant 8 (72%) of the 11 MLE in this study had appropriate BNL if the International classification scale was used (see Figure 9).

The researcher had anticipated that the BNL in TRAD rooms ought to be considerably lower than those found in the MLE as a consequence of the reduced number of children present, coupled with the four walls separating the children from the adjacent classes. The results did not sustain this assumption, as mentioned previously, the mean BNL for the TRAD rooms was 51.5 dBA which is not too dissimilar to the BNL for MLE which was 54.3 dBA. Our results did show that the mean BNL in TRAD rooms was lower, than those in MLE, however, the level was not as great as the researcher had expected. These results must be interpreted with caution, as there was considerable variance within the data sets (SD=7.5 in MLE, SD=6.7 in TRAD)

While these findings came as a surprise to the researcher, as several earlier investigations have reported higher noise levels in MLE classrooms (Finitizo, 1988; Mealing, Demuth et al, 2015). The results from the current study however, are consistent with what some other previous studies have found (Barnett et al., 1982; Finitzo TJ Roeser RJ 1988; Fitzroy & Reid, 1963; Kyzar, 1971; MacKenzie, 1999). These researchers investigated open-plan and traditional enclosed rooms. Barnett et al, found no significant difference in BNL between classroom types when they reported on a traditional room occupied by thirty pupils and an open plan space with sixty pupils. Fitzroy and Reid, found the difference between these two classroom styles to be less than two decibels, as did Kyzar. Finitzo, was the only study which noted a significantly higher average of just three dB in an open plan room which contained 100 pupils. A caveat to this finding is that the style of open plan space used in that study is quite dissimilar to the current designs which favour a linear rather than a square cluster of class bases.

The McKenzie and Airey study found that open plan rooms actually had a BNL which were up to five decibels lower than the traditional spaces. They did acknowledge that this finding was somewhat dependent upon the activity being undertaken at the time. Consequently, they also reported that the occupied BNL during some activities was higher than predicted in the fully enclosed rooms. These results are similar to the outcome of the present study which uncovered a range of noise levels which were not perceptibly better in one style of classroom compared to the other. Several explanations have been posited for the limited variance of BNL levels between MLE and TRAD, these include lower RT times and better acoustic absorption in some MLE. (McKenzie & Airey, 1999) It has also been surmised that teachers in open plan rooms make more of a concerted effort to contain noise levels as their awareness of the impact of BNL on adjacent class bases was probably higher (McKenzie & Airey, 1999). This level of control may not seem quite as imperative in rooms which contain only a single class.

There are numerous reasons to mitigate the effects of excessive classroom noise levels. A considerable amount of literature reports negative outcomes for children's social and educational attainment as a consequence of stress from excessive noise levels (ASHA, 2005; Crandell &

Smaldino, 2000; Finitzo-Hieber & Tillman, 1978) There are known physiological consequences of noise exposure, these include elevated stress levels, and heightened blood pressure, and tiredness (Anderson,2001; Shield et al.,2010). High noise environments can affect several facets of a child's education, in particular their ability to focus and concentrate, and subsequently their motivation. Ultimately, these noise levels can impede a child's understanding of language including the ability to read (Crandell & Smaldino, 2000; Klatte, Lachmann & Meis, 2010; Maxwell & Evans, 2000; Ronsse & Wang, 2013; Shield et al., 2010). `

Teachers too can succumb to the consequences of excessive noise levels. In order to be heard above the background noise, they must speak louder to achieve a suitable signal to noise ratio – preferably fifteen decibels higher than the prevalent background noise levels (Anderson, 2001; Greenland & Shield, 2011; Mealing, Demuth et al, 2015). Consequently, incidents of vocal strain or ongoing throat conditions and sometimes increased sick leave can occur as a result of their occupational environment (Pelegrín-García et al., 2014; Sapienza et al., 1999; Shield & Dance, 2014) (Kristiansen et al., 2016)

Perhaps the most salient point from this project is the disagreement between recommended BNL from a government department of education in NSW Australia, and International research. Both advocate the minimising of background noise, but the Australian scale may suggest levels which are somewhat less achievable than the International levels simply as a consequence of the number of children in that space. New Zealand is often influenced by trends in Australia, at least one Principal in this study remarked that they had visited MLE schools across the Tasman to assess their suitability for NZ children. There exists the possibility that expectations of what constitutes "acceptable" BNL for an Australian Dpt of Ed could potentially be adopted by the MoE here in Aotearoa/NZ. The author of the present study would certainly advocate for a wider range of acoustic parameters (such as the four used in this study) to be adopted by the MoE. However, should such measures come to be added to the DQLS it would seem prudent to adopt the recommended BNL in the International scale, as these appear to be more realistic compared to the more stringent levels suggested by the NSW Dpt of Ed.

The MoE DQLS-acoustics 2016v2 has included several measurements which were formerly just recommendations, but are now requirements. It may be beneficial in the future for this document to place tighter restrictions on other areas of the document which are currently still guideline status only. Testing for BNL levels for example may be one of these. It is anticipated that a reduction in the numbers of children sharing these MLE learning spaces could conceivably yield BNL performances which are more desirable than some of the levels currently being reported in the literature, and which were also replicated in some MLE in this study.

At the present time, to the knowledge of this author, no empirical model exists which accurately connects, activity levels, room acoustics, and speech levels for pupils (Pelegrin-Garcia, 2014). However, Two NZ Acousticians, James Whitlock, and George Dodd have attempted to develop a predictive model for classroom noise levels which they describe as currently at a “fledgling stage”. Largely, as a consequence of incorporating the Lombard coefficients into their equation alongside several other pertinent variables they may have developed a possible method for identifying some of the aspects of classroom noise, which in turn has implications for classroom design (Whitlock & Dodd, 2008).

The upper limit for acceptable occupied Background Noise Level (BNL) in TRAD classrooms recommended by the AUSTRALIAN SOUNDOUT CLASSROOM ACOUSTIC

APP, is <50 dBA. Results show, 1 of the 11 (9%) TRAD in this study had ‘good’ green ratings, that is the occupied BNL in the classrooms was below forty five dBA. A further 5 of the 11 (46%) had BNL between 45-50 dBA which corresponds to an ‘OK’-Orange rating. Additionally, 5 of the 11 (46%) of TRAD classrooms had BNL greater than 50 dBA which is indicated by the “Bad”- Red rating. Overall, 6 of the 11 (55%) TRAD rooms in this investigation met the Australian SoundOut App requirements, for acceptable BNL, and 5 (46%) did not. These results are represented graphically in Figure 10.

The upper limit for acceptable occupied Background Noise Level (BNL) in TRAD classrooms recommended by the INTERNATIONAL MEALINGS CLASSIFICATION is 55 dBA. This research showed 5 of the 11 (46%) TRAD rooms in this study met the Mealings criteria for a ‘Good’- ‘Green’ rating for BNL which was below fifty dBA. Additionally, 4 of the 11 (36%) achieved an ‘OK’ or orange rating. That is the BNL in the classrooms was between 50-55 dBA. A further 2 of the 11 (18%) TRAD rooms recorded BNL in excess of 55 dBA which meant they scored a ‘Bad’ red rating. Overall, 9 of the 11 (82%) TRAD in this investigation met the International Mealings Classification requirements for acceptable BNL and 2 (18%) did not. These results are represented graphically in Figure 10.

<u>SPEECH TRANSMISSION INDEX</u>

The MoE in Aotearoa/NZ like many other countries has adopted an “inclusive” approach to the schooling of all children irrespective of any physical, social or emotional differences that may be present (Kearney & Kane, 2006) As such, the great majority of children, even those who present with learning challenges will be mainstreamed into classrooms with other normally developing youngsters. Room acoustics have a significant role to play in ensuring that children can learn in the most conducive environment possible. Research suggests this occurs when the youngster is able to receive a pure acoustic signal from their educator (Bracket,1997) The STI provides a score which can predict the intelligibility of syllables, words and sentences in a room (Steeneken & Houtgast, 1980). Thus, it is an invaluable tool for assessing the efficacy of classroom environments.

Hearing speech clearly is critically important for all children but particularly for those youngsters who have special learning needs such as those with delayed language, or for whom English is a second language, some may be on the autism spectrum (ASD) or exhibit attention deficits hyperactivity disorders (ADHD). Others may have auditory processing disorder (APD) or an identified hearing loss (Anderson, 2001; Crandell & Smaldino, 2000; Nelson & Soli, 2000). Estimates in this country suggest that ninety percent of children with a permanent sensori-neural hearing impairment are incorporated into mainstream classrooms (Valentine, 2002) What remains unknown is the number of children who could at any time be affected by one of the most common childhood ailments: namely a transient conductive hearing loss due to Otitis Media. Ostensibly, hearing loss can be thought of as an unseen issue, as both its symptoms and outcomes are not necessarily obvious to others around the child, which means the condition has the potential to go unnoticed (Ross, 1991). This situation is particularly disconcerting in a classroom situation as it means afflicted youngsters have a heightened risk of having reduced language and reading abilities, appearing distracted, or reacting erroneously to instructions. Unfortunately, these behaviours can also be wrongly identified as pertaining to learning or behavioural issues (Bracket, 1997).

One of the most salient reasons for using the STI score to assess the acoustic properties of a classroom is that it is an operational measure which acknowledges the cumulative impact of other acoustic features of the space under measurement, including the RT, and the BNL. Many evaluations of classroom acoustics are solely based on unoccupied measurements such as ANL and RT which is the case in NZ MoE DQLS v2. Measures such as BNL and STI are invaluable as they provide functional acoustic information about a room when it is occupied and operating as a learning space. A caveat to this is that the STI value is that it provides a reading which can be changeable due to the interaction between background noise levels and RT. For example, a classroom which has good RT, but high BNL will yield a poor STI. The same room could with lower BNL could yield a suitable STI. So, to some extent, STI scores like BNL can be a result of classroom management by the teacher. Also, some schools may have different cultural norms around what they consider acceptable BNL. The STI measurements in this study were conducted when children were involved in independent work such as reading, writing, or colouring as opposed to group activities which naturally produce more BNL. It was surmised that these levels were more likely to replicate, or be synonymous with periods of critical listening which might occur in the classroom. It was further posited that, measuring during independent work would yield more salient information regarding the accessibility of the component parts of speech.

Having optimum clarity around the speech signal is vital for all children to learn language skills. It becomes even more important when consideration is afforded to catering for the mainstreaming of children with hearing loss. Irrespective of the attenuation caused by a hearing loss it is still possible for the speech signal to remain at a suitable level of intensity to make it audible to children, but it is probable that the speech, especially the phonemes will be distorted or filtered out completely (Johnson, 2000). Subsequently, the child’s perception and storage of phonemes is rendered inaccurately, which has both short and long term linguistic consequences. In particular, reading and literacy are acutely negatively impacted (Ling, 2002; Flexer, 2004;

Ross, 1991). Longitudinally, such poor auditory mapping has the potential to be associated with lifelong learning and communication difficulties including APD (Clegg, 2006; Cunningham, et al, 2001; Hornickel & Kraus, 2013; Johnson, 2000; Ziegler, et al, 2009) These issues are often perplexing to all concerned, since they appear to have no specific distinctive or universally acknowledged neuroanatomic, or neuropathological basis. Research is ongoing in these areas which may indicate that fluctuating hearing loss and the associated periods of auditory deprivation could potentially be linked to delayed and reduced myelination of the auditory pathways (Chermak & Musiek, 2011; White-Schwoch, Davies, Thompson, et al, 2015).

The push for improvements to classrooms acoustics ostensibly began in North America some 25-30 years ago. It is therefore unsurprising that two organisations from this region issued statements decrying the merits of teaching children in open-plan facilities. (Canadian Standard for School Facilities (2001) and ANSI (2002). These two bodies concurred that the negative consequences of this style of educational building was the unacceptably high noise levels which resulted. They proposed that any merits from this open plan style of shared teaching space would effectively be voided by the unfavourable impact of the heightened noise levels.

Many nations have expressed concerns around the acoustic properties of facilities in which children are taught. This has led to the introduction of acoustic standards around the globe. The most stringent were initially introduced in North America, in 2002, (updated in 2010). followed in 2003 by countries in the UK: Wales and England. New school builds in these last two countries are required to meet standards issued in the Building Bulletin 93 (BB93) which specifies, the ANL, RT, **<u>and a mandated requirement for open plan classrooms to have an STI value of 0.6 or better when they are occupied</u>**. The only two other countries which have incorporated the STI recommendations into their national standards are Denmark in 2004 and

Iceland in 2011 (Mealing, 2016). Academics from several other countries have suggested appropriate STI values in their research, but few of these recommendations appear to have been incorporated into legislative requirements as yet. This may be the best way forward for many countries, who like NZ are rapidly adopting MLE style of classrooms. The inclusion of STI values in the legislation pertaining to MLE would serve the dual purpose of ensuring speech was able to be discerned clearly, but more importantly, that background noise levels would have to be managed to achieve these scores. As such, this could necessitate future MLE builds being based on lower student densities occupying these spaces. The current study, demonstrated 8 of the 11 (72%) MLE and 9 of the 11 (81%) TRAD attained suitable STI scores of 0.6 or more.

The remainder of this discussion section will focus on the three additional hypotheses, (B, C, D) and conclude with an examination of Research Question Two, regarding the overall performance of the classrooms in this study.

CORRELATION BETWEEN NUMBER OF CHILDREN IN A CLASS & BNL

Hypothesis B mooted that there would be no significant correlation between the number of children in a class and the occupied background noise levels (BNL). Using a non-parametric Spearman's correlation, these findings, did reach levels of statistical significance at the 0.05 level (1-tailed) meaning hypothesis B was not supported at this level. The examples in the present study did find that the increased number of pupils concentrated in MLE environments meant they tended to be associated with louder background noise levels than those recorded in more traditional environments.

The trend toward higher BNL levels in MLE in conjunction with the finding of a slight positive correlation between the number of pupils per learning space and higher levels of background noise there may provide sufficient reason to be concerned about the suitability of the MLE environment as an optimal learning space for children (Mealing, Demuth et al, 2015; Shield, Greenland & Dockrell, 2010). This finding is in agreement with research which has identified a significant relationship between the BNL and number of pupils in a room (Maxwell & Evans, 2000; Shield, Greenland & Dockrell, 2010; Shield & Dockrell, 2003). Occupant density has been identified as perhaps the foremost contributing factor to the levels of background noise and subsequent distraction in teaching spaces, (Corrie, 1974; Walsh, 1976; Greenland,2009) It also contributes to the levels of annoyance reported by both students and teachers (Brannstrom, et al, 2017; Connolly et al, 2013; Persson, et al 2015; Valentine, 2002).

The literature emphasises that the management of other acoustic features such as acoustic absorption, or room partitions or allocated space per child were less effective ways of bringing down the BNL compared to reducing the concentration of students in a space (Walsh, 1976, Greenland, 2009). The findings of the current study also support this approach, given that the BNL were slightly positively correlated with the number of pupils sharing a teaching space. As MLE allow for the presence of higher allocations of pupils in a confined space they may be considered less conducive listening and learning spaces. The addition of absorptive materials enabled a three-five decibel reduction in BNL, compared to the six to ten decibels which could be achieved by decreasing the number of children inhabiting a classroom space (Walsh, 1976; Greenland, 2009)

One feature which appeared to be absent in all the MLE visited during this project was the presence of any "mobile partitions" between class bases. These can take the form of bookcases, storage furniture, moveable panels or suchlike. These dividers are encouraged in the literature and the NZ MoE DQLS guidelines as they are mooted to provide some level of acoustic privacy between class bases sharing a larger space, and as such may reduce some of the deleterious effects of background noise which contains speech (Grayson, 2010; Whitlock,2016) One study reported that utilising these fittings could produce BNL which were attenuated by six to nine decibels (Kyzar, 1971). The notable absence of portable dividers may be unique to Christchurch, as a consequence of the recent disastrous earthquakes in the region. There exists the very real possibility that these moveable dividers could fall on children, causing physical harm. Additionally, there is potential for psychological harm to some youngsters in the region who may harbour psychological fears regarding the possibility of such occurrences (Johnson, et al, 2014) Acoustic consultants do advocate their use in MLE, however they may be more appropriate in less seismically active countries, than Aotearoa/NZ. The reasons for the absence of these mobile dividers was not explicitly explored in this study.

ACOUSTIC RECOMMENDATIONS FOR CHILDREN OF DIFFERENT AGES

Hypothesis C asserted that there would be no significant difference in any of the acoustic parameters for younger or older age groups. This hypothesis was found to be supported. In this investigation, younger children were classified as those aged between five and eight years, and older children were classified as those aged between nine and twelve years. Specific age-related acoustic recommendations have been proposed by Mealings, (see Table 4). Due to a lack of power in this current study, direct comparisons were unable to be made between the age brackets in the Mealing chart, and the ages divisions of the participants in the Christchurch schools. Additionally, the schoolchildren in the Christchurch schools were combined into classes which included a wider age range when compared to the more delineated classes in the Australian study. Further, there seemed to be considerable variability between the schools as to how they combined the ages of children being taught together. For example, some rooms had children aged 5,6, together, others had 5,6,7, others had 5 year olds only. Still others had combinations including pupils aged between 6,7,8 years, or, 7,8,9. Instead, for the purposes of this investigation, which was essentially, a scoping exercise, it seemed more appropriate to divide the two cohorts into just the two categories, of younger and older.

Statistical analysis revealed there was no discernible differences between the acoustic conditions (ANL, BNL, RT, STI) in which younger children (5-8 years old), or older children (9-12 years old) were being taught. While these findings were not unexpected, they were disappointing as it appears to suggest that there is little recognition for the additional acoustic needs of younger learners. Researchers have long advocated that younger children in particular require superior acoustic conditions to learn in (Hall III, Buss, & Grose, 2005; Leibold & Buss, 2013; White-Schwoch et al., 2015; Wightman, 2005). It is clear that younger children require excellent acoustics in order to hear the components of speech clearly to ensure they encode language accurately (Hall III et al., 2005; Leibold & Buss, 2013; White-Schwoch et al., 2015; Wightman, 2005)

However, there is a mounting body of research which demonstrates that older children also benefit from better acoustics. Although these reports seem to suggest that the benefit derived by both these groups may be for subtly different reasons. Whereas it is presumed that older children will have better language skills, but the evidence from studies using neurological imagery demonstrate the cortical areas of the brain are still actively proliferating and thickening into the teenage years (Johnson, Blum, & Giedd, 2009). These findings agree with recent studies involving students in secondary schools who also report being negatively affected by noise to varying degrees. They reported greater levels of annoyance, more difficulty concentrating, had poorer speech perception and generally found it more taxing if verbal processing was required

(Brannstrom, et al, 2017; Connolly et al, 2013; Persson, et al 2015)

HEARING/LANGUAGE IMPAIRED CHILDREN IN CLASSROOMS

Hypothesis D mooted that there would be no significant difference in any of the acoustic parameters found in classrooms where children with identified hearing/language impairments are taught.

No statistical analysis was conducted for this question due to low numbers of children in the study who had an identified hearing loss, (five in total, four were educated in a TRAD classroom, one attended a MLE). However, an interesting trend did emerge in which more children who did have an identified hearing loss were being educated in TRAD classrooms rather than MLE. It is unknown whether this is a deliberate choice made by the parents of these children, or not. This may be an area for future research with particular focus on the notion of inclusivity in education.

Such research could be particularly helpful in gaining much needed increase in government funding for permanent or trials of personal FM systems for children with confirmed, or suspected APD, and or learning and behaviour issues. This is an area which is noticeably under-resourced, and under-funded within the NZ education system (Wright & Esplin, 2014) Failure to provide adequate technical support in the form of personal FM systems has the potential to have life-long negative consequences for children exhibiting such difficulties (Wright & Esplin, 2014) Research seems to acknowledge that increasing the numbers of children in a space is likely to subsequently raise the background noise levels due to the Lombard/café effect (Whitlock, 2006) One acoustic consultant remarked (in personal correspondence with the researcher) that the "MoE is committed to the concept of MLE, - the cat is out of the bag so to speak”. Hence, the necessity of Providing more FM systems, along with additional support may be one of the un-intended costs/consequences of the new pedagogical, and acoustic environments synonymous with the background noise generated by the large numbers of children taught together in MLE. In the current study, all four children with an identified hearing loss were being taught in TRAD classroom and only one was in a MLE. In the future as MLE become more prevalent, there exists the distinct possibility that parents may not have the option of selecting which environment their hearing-impaired child is educated in. Ultimately, this may warrant additional MoE funding for personal FM systems, specifically in regard to the cluster of learning/behavioural problems, including APD which may be associated with difficulties in noisy situations. This is likely to become more of an issue if the MoE intends to meet its objectives for an “inclusive” style of schooling (Sharma & Purdy, 2014)

After examining the international research the 2016 Mealing study produced a separate chart of optimal acoustic parameters considered necessary for the additional needs of children with hearing or language impairment (Airey, 1998; Association of Australian Acoustical Consultants, 2010). In summary, these recommendations were ANL less than 20dBA, BNL < 40 dBA, RT< 0.3s, STI >0.75. In order for a teaching space to be considered suitable for the education of children with hearing/language impairments the space would need to meet all these criteria to qualify for a ‘Good-Green rating under these considerably more stringent criteria. Unsurprisingly, none of the classrooms in the current study either MLE or TRAD met all four acoustic parameters at the levels considered to provide the ideal (good-green) listening environment for youngsters with hearing/language impairments. This finding was consistent with other research which suggests that many current teaching environments are far from ideal for the very youngest children and those with additional learning needs (Mealings 2015, Wilson, 2002). The insidiously negative impact of the Lombard and café effect mean children with additional learning needs warrant extraordinary consideration when it comes to assessing the suitability of a classroom. It seems that for these children in particular, a smaller enclosed space which guarantees a finite number of classmates is still expected to provide a more conducive acoustic environment for this special group of learners.

It appears that MLE are set to become an increasingly prevalent style of classroom within the NZ public education system as a consequence of the more open, fluid, child-focused opportunities they provide (Benade, 2015; Bolstad et al, 2012; Campbell, Saltmarsh & Drew, 2013; Osborne,2013). If the pedagogical changes and their associated architectural changes are to serve young learners well, the literature suggests the following conditions relating to acoustics ought to be adhered to. It is noteworthy, that many of these recommendations now appear in the revised MoE DQLS –Acoustics 2016 v2.

First and foremost, maximum absorptive materials should be applied to every available surface including ceiling, walls, floors, to maximise speech perception and reduce internal noise from furniture, and children's feet (Greenland & Shield, 2010; Sieben et al, 2000; Whitlock, 2016) A limit of three class bases within any one teaching space to attempt to reduce teachers vocal strain, and contain the lombard/café effect of "noise breeding noise" (Whilock & Dodd, 2008; Greenland & Shield, 2010) Personal FM systems should be deployed to increase the signal to noise ratio particularly for children with learning and or listening needs (Flexer, 1992; Wilson, 2002). An apportionment of space which equates to 4-5m^2 per student, with a "buffer zone" allowance of 6.5 metres between adjacent class basses (Shield, 2010) Additionally, moveable barriers between 1.6m and 2 metres are also recommenced (Shield, 2010) This is to enable children to be gathered close to their teacher to increase the SNR, maintain high STI, and contain some of the contaminating effects of adjacent BNL, especially verbal noise (Sieben et al, 2000). It is recommended that ceiling heights should not exceed 3.5m, and they should have absorbent material on 90% of the surface to reduce RT and BNL (Shield et al., 2010; Siebein et al., 2000; Wilson, 2002). Break-out rooms need to be incorporated into designs to ensure children have the opportunity to work in a quiet space when required (Mealings, 2015). Ambient noise from equipment, air conditioners, computers needs to be restricted to the lowest possible levels to prevent children and teachers having to raise their voices significantly above these sounds, which risks the Lombard/café effects coming into play (Whitlock & Dodd, 2006)

Given the essentially prohibitive cost to schools of having the acoustics of buildings assessed, ($1,600/day approximately from personal correspondence) an alternative may be to use the customised NAL 'SoundOut' App. at least as a starting point. It may be an efficacious, efficient, simple, and extremely cost effective means of collecting initial classroom acoustical data on either a small or a large scale. There are many sectors of the community with a vested interest in classroom acoustics, many of these groups have complimentary roles in the education of children (Smaldino et al, 2004). The list includes, parents, teachers, SLT, and audiologists who do not have the training of an acoustic engineer, but the NAL Sound-Out App presents them with a validated tool to initiate some preliminary measurements which would hopefully result in remedial action being undertaken when concerns around sub-optimal acoustics are raised. One of the features of the app is the provision of simple solutions to combat some common acoustical issues. Once this data is compiled, it may provide useful empirical evidence to present to individual school boards to support the provision of additional funding for acoustic treatments to substandard rooms. Or perhaps schools could forward their data to the MoE (as the technical owners of these open-plan buildings) again to secure supplementary funding to increase the acoustic performance of these spaces. Given the wide range of building designs across the country, each classroom is likely to have a unique set of fittings and bespoke materials, which will influence their overall acoustics, hence it is vital that each room is evaluated on a case-by-case basis.

Additionally, the ‘SoundOut’ App can be employed subsequent to any modifications to verify the efficacy of these treatments. One of the real benefits of this simple app. is the ability for data to be collected nationwide on a large scale across a wide variety of classroom spaces. Something which is pointedly lacking in the available research which tends to focus on just a few classrooms at a time. Once this research has been undertaken, it may be useful for certain governing bodies within Aotearoa/NZ to ensure the current DQLS acoustical guidelines for MLE are legally mandated to ensure speech perception is not compromised for young learners.

OVERALL ACOUSTIC PERFORMANCE OF MLE AND TRAD CLASSROOM

Research question two asked whether recommendations from either NZ Australia or International scales showed MLE or TRAD classrooms generated better “overall ratings” when all the four parameters were considered collectively, namely: “ANL”, “BNL”, “RT” and “STI” (Ambient Noise Level/Background Noise Level/Reverberation Time/Speech Transmission Index).

These results from this question ought to be interpreted with the requisite caution, as no formal statistical analysis of this question was undertaken. However, there were some interesting outcomes when an “overall” comparison was made between the acoustical parameters recorded in the MLE and TRAD. The current document outlining the acoustic requirements for classrooms in NZ is entitled the DQLS, 2016 v2 and like many other countries in the world, (for a comprehensive list, see Mealing, 2016) the DQLS outlines just two specific acoustic measurements, ANL and RT. Both these factors are tested when the classroom is unoccupied. However, a more accurate picture of the overall acoustic performance of a teaching space can be obtained when additional acoustic measurements are recorded when the classroom is occupied. Evaluating the BNL and STI scores adds valuable acoustic data about the acoustic health of a space when it is operational. Obtaining data about the functional capacity of classrooms has become increasingly pertinent as both the style of teaching, and the style of classrooms has changed rapidly in recent years. Classrooms have become bigger and now have higher occupancy rates than in the past. Substantial learning occurs through group activities rather than teacher driven presentations (Ling, 1988; Nelson & Soli, 2000). As a consequences of these changes there is a greater likelihood that children are learning in noisier environments (Nelson & Soli, 2000). Research estimates that youngsters spend between forty five and seventy five percent of the time listening to either their teacher or other children. Therefore, it is imperative that contemporary learning environments are suitably designed, and hence fit for purpose.

An increasing array of studies have investigated the efficacy of current classroom spaces as environments conducive to good listening and hearing for children. One recent paper investigated the acoustic parameters found in classrooms throughout the world (Mealing, 2016) The findings were subsequently reported along with various national standards, and academic recommendations from around the globe. These guidelines were later collated into a series of tables which outlined appropriate occupied and unoccupied classroom acoustics. These globally derived recommendations could be conceived of as representing current universal best practice guidelines for the acoustics of all styles of primary school classrooms.

The current study aimed to benchmark an array of typical primary school classrooms found in Aotearoa/NZ against the tables in the 2016 Mealing paper. The purpose of this evaluation was to assess the acoustic circumstances in which listening and hearing activities occur for young children in the education system. A particular focus was the effect of these environments on those with hearing difficulties or additional learning needs. The results from the current study demonstrate the benefits of testing a wider array of acoustic parameters as can be seen in Figures 14-16.

Evaluating just the two unoccupied measures recommended in the MoE DQLS showed that Using the NZ MoE DQLS as the rating scale, 11 of the 11 (100%) MLE, and 11 of the 11 (100%) TRAD classrooms met at least one of the recommended acoustic parameters, either ANL, (<45dB LAeq) or RT (MLE=0.4-0.8s/TRAD=<0.5s) Additionally, 9 of the 11 (82%) MLE, and 8 of the 11 (72%) TRAD classrooms met both of the recommended ANL and RT. In total, combining, both MLE and TRAD rooms, 17 of the 22 (77%) rooms surveyed in this study met the current DQLS 2016 recommendations

Alternatively, using the four measures from the Australian NSW Dpt of Ed, the results showed a grading of "OK" was achieved by 8 of the 11 (73%) MLE, and 9 of the 11 (82%) TRAD classrooms met 3 or 4 of the recommended acoustic parameters, namely ANL, (<45dB LAeq) RT (MLE=0.4-0.8s/ TRAD=<0.5s) BNL(=45-50dBA) and STI(= 0.6-0.7) Additionally, 4 of the 11 (36%) MLE, and 8 of the 11 (73%) TRAD classrooms met all 4 of the recommended acoustic parameters including ANL, RT, BNL and STI. In total, combining, both MLE and TRAD rooms, 17 of the 22 (77%) rooms surveyed in this study met the current 3 or 4 of the AUSTRALIAN (NSW Dpt of Ed) recommendations. In total, combining, both MLE and TRAD

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rooms, 12 of the 22 (55%) rooms surveyed in this study met all 4 of the AUSTRALIAN (NSW Dpt of Ed) recommendations.

But when the International Mealing criteria were invoked, the results showed a grading of “OK” was achieved by 8 of the 11 (73%) MLE, and 9 of the 11 (82%) TRAD classrooms met 3 or 4 of the recommended acoustic parameters namely ANL, (<45dB LAeq) RT (MLE=0.4-0.8s/ TRAD=<0.5s) BNL (= 50-55dBA) and STI (= 0.6-.75). In the final analysis, only 5 of the 11 (45%) MLE, and 7 of the 11 (64%) TRAD classrooms met all 4 of the recommended acoustic parameters including ANL, RT, BNL and STI. In total, combining, both MLE and TRAD rooms, 17 of the 22 (77%) rooms surveyed in this study met the current 3 or 4 of the INTERNATIONAL (MEALING) recommendations. **Just, 12 of the total 22 (55%) classrooms surveyed in this study met all 4 of the INTERNATIONAL (Mealing, 2016) recommendations from Table 3.**

As a consequence of evaluating the classrooms in the current study under these different scales it became apparent that testing classroom acoustic performance over four parameters rather than just two yields a more accurate profile of the true functional acoustic environment each space presents. Several countries including, England, Wales, Denmark and Iceland have introduced national standards which mandate the STI values for primary school classrooms. This offers yet another means of substantiating optimal classroom design standards across all styles of teaching and learning spaces. If Aotearoa/NZ is to meet its obligations to provide ‘inclusive’ education facilities under the WHO guidelines, it may be advantages for the NZ MoE to consider adopting additional acoustic testing, particularly occupied measures to ensure that ALL learners in primary school classrooms can learn in spaces optimised for hearing and listening (Gal et al., 2010; Eriks-Brophy, 2013; Sharma & Purdy 2014, van Reenen & Karusseit, 2017)

The global attitudinal shift towards 'inclusivity' can be largely attributed to the (World Health Organisation, 2001) remit, known as the International Classification of Functioning, Disability, and Health. The contemporary focus is now on physical and social environments that might impede or facilitate an individual's successful participation in everyday life. The education system is viewed as having a significant part to play in enabling these goals (Gal et al., 2010; Eriks-Brophy, 2013; Sharma & Purdy 2014, van Reenen & Karusseit, 2017).

8.0 Study Limitations

This project had several limiting factors, namely its reduced geographical location, small sample size, and experimental design, each of these factors may have had an unintended effect on the outcomes of this study.

To begin with, one initial limiting factor is a consequence of the restricted geographical location of the study, namely urban schools in the city of Christchurch. While some classrooms were part of primary schools in the wider Christchurch region, they may not be representative of classrooms across NZ. It was not feasible to control for the location of the primary school nor its decile rating. It is also likely that the rural setting of some schools meant they were less likely to experience noise interruptions present in the surrounding environments of contemporary urban classrooms. These differences in physical location may have created unforeseen variability in the baseline classroom listening environments (Shield & Dockrell, 2002; Shield & Dockrell, 2006)

A second limitation concerns the number of classrooms which were able to be tested due to limitations on the time and funding available for this project. These two factors meant there were only eleven traditional classrooms and eleven modern learning environments examined for their acoustic properties. The small scale of this investigation means caution should be employed when interpreting these findings which may, or may not be representative of the acoustic properties of the overall classroom stock held by the Ministry of Education. Future research ought to include a greater total number of classrooms, which would subsequently produce heightened statistical power of analysis and enable more valid conclusions to be drawn. Allied to this, is a raised awareness of the sheer number of children being taught in these two different types of classrooms, and the impact of architecture and acoustics on speech comprehension.

A third limitation relates to controlling for physical variability, or 'degree of openness' in the MLE classroom environments being measured. For reasons of transparency, the appendix contains detailed descriptions and photographs of each classroom tested. The teaching spaces were divided into either traditional, or MLE, but within these two classifications there was considerable diversity of the architectural features, which could not be controlled for. Factors which may have had an impact on the measurements include, number and size of windows which are hard reflective surfaces for sound to bounce off, which may have impacted on the RT. They also allow some external environmental noise into the room. The total physical volume of the space under consideration. The presence or absence of acoustically absorbent materials on the ceiling and or walls, along with the presence of "doors" or "room dividers" could have impacted on the results measured.

Similarly, interior decorations varied between classrooms. Features such as the number and variety of soft furnishing like curtains, carpet, bean bags, cushions, padded room dividers which were present in the space. These items have the ability to absorb sound, and thus reduce the RT. Other features such as pin boards on walls, pictures hanging from the ceiling function in a similar way to reduce the RT.

Ambient noise measurements suffered from similar variability which may have impacted the measured results. Classrooms exhibited a varied array of equipment which was turned on during the recordings. These included air conditioning units, heaters, computers, projectors, fish tanks and so forth. This information is annotated in the appendix, but again was not controlled for during the measurements.

Along a similar vein, the material which was taught during the experiment was identical across all classrooms, however the manner in which it was delivered may have varied as a function of natural differences in teaching styles adopted by the individual teachers concerned. While these uncontrolled factors may have contributed to some variability across the data sets, ostensibly, they also contribute to the “real world” face validity of these results.

8.1 Future Research Directions

The NZ Ministry of Education is anticipating a surge of around 16,690 new students into the education system by 2020, the current funding model allows for capital expenditure of approximately $3.5 billion, this figure represents a $1.1 billion dollar shortfall in funding required to manage the forecast student growth. (retrieved from Treasury, pre-budget 2018) It is imperative that future research into classroom acoustics is cognisant of the fiscal constraints currently facing both the Ministry of Education and hence individual school boards. This lack of funding means research ought to focus on the commercial imperatives driving some of the architectural design processes and evaluate whether or not they can meet both the new pedagogical aspirations and continue to provide equitable, quality facilities for teaching and learning.

Contingent upon this, is a re-examination of the MoE requirements for schools to include MLE in their ten-year plan may well be warranted. Particularly given the current government which has pledged to ensure all NZ schools had access to MLE by 2030. Greater focus on mandatory compliance with the acoustical measures outlined in the MoE DQLS 2016 would be preferable to the current situation where educational spaces can seemingly be created but not necessarily legally required to comply with any specific national standards. In England, and Wales in 2003 the introduction of legislation pertaining to school acoustics (RT and ambient noise) has gradually improved acoustics in classrooms. One 2015 investigation into 185 different teaching spaces across thirteen high schools in England indicated that the number of teaching spaces which complied with the required 2003 standards had doubled, and was now up to almost ninety percent (Shield & Conetta, 2015).

In this country, the professional body representing audiologists, the New Zealand Audiological Society (NZAS) has issued a position statement on classroom acoustics in which they share the concerns of many international researchers (Mealings et al, 2016; Wilson et al., 2018). This has led the association to provisionally suggest that "*further updates to the DQLS (2016) Acoustics document must provide steps for enforcing classroom acoustics standards.*" (Wilson, et al, 2018). The Society made two further comments, given that it believes that many boards of trustees, and principals are aware of issues around noise and acoustics in learning spaces. Their first recommendation emphasized the need for the MoE (as the ultimate owner of classrooms) to abide by proper acoustic designs in the capital projects it funds. The second recommendation endorsed classroom acoustic design being prioritised at the design stage rather than retrospectively as research has demonstrated this was the most cost effective approach (Canning & James, 2012).

In 2007 the Australian government commissioned a report focusing on policies aimed at raising both literacy and numeracy abilities of younger children as this was considered a critical pathway to create the requisite workforce skills for a functioning society (Anderson, 2001; James, Stead, Clifton-Brown, Scott, 2012) Subsequently, an Australian team of researchers have further extrapolated on the cost benefit aspects of providing acoustically ‘sound’ environments in educational facilities. They used the criteria outlined in the newly developed ‘Guideline for Educational Facilities Acoustics’ (2010) published by the Association of Australian Acoustical Consultants. James and colleagues conducted a cost/benefit analysis which assessed the higher initial costs of construction against the longer term economic outcomes. Specifically, the long-term effect on individuals in the workforce. Reasoning that productivity and participation are highly influenced by the level of education attained by an individual, as these factors are also correlated to wages. Like earlier research, they too concluded that the long-term benefits to students considerably outweighed the initial increased construction costs (Shield & Dockrell, 2008; James, Stead, Clifton-Brown, Scott, 2012; Shomos, 2010)

It is to be hoped that future investigations will contribute some useful empirical data to the current debate regarding the efficacy of MLE, in particular some of the occupant density rates which impact so significantly on background noise levels. Sub optimal acoustics have been linked to reduced educational outcomes for pupils, poorer speech understanding and increased vocal strain on teacher’s voices. Furthermore, inferior acoustics are known to have a greater impact on children with: hearing loss, learning difficulties and those for whom English is a second language (Peng & Wang, 2016). As the MoE requires school design to be “inclusive” of all these groups, acoustic benchmarks become even more significant. Research has concluded that pupils from the aforementioned groups require a reduction in ambient noise of approximately ten decibels compared to others of the same age (Crandell & Smaldino, 2000; Nelson & Soli, 2000).

Alongside these objective investigations, it would be beneficial to include some research which considers the more subjective components of modern educational spaces by their end users, i.e. the students and teachers. The Essex Study – Optimised classroom acoustics for all is one such project which has endeavoured to systematically examine the consequences of limiting RT and noise by implementing a variety of acoustic treatments to classrooms. These treatments were then evaluated, objectively and then subjectively by children and adults who used these spaces. The results are a testament to the worthiness of improving the acoustic learning environment (Canning & James, 2012). In NZ, a small pilot study involved 23 children in a single-cell classroom performing a mapping and colour coding exercise (Legget, 2015). The children had to codify spaces within their classroom as 'noisy', 'quiet' or 'difficult' spots to hear the teacher talking. These results were then combined with the objective measurements and teacher interviews to identify problem areas within these spaces. The purpose of including these subjective measurements was to facilitate building designers' ability to predict whether various acoustical features would meet the required performance criteria of the learning spaces. Conducting a similar exercise in a MLE environment could potentially yield equally useful design data (Leggett, 2015). That project stemmed from a 2005 questionnaire designed by the Charlton Smith Partnership who are an architectural acoustic consultancy firm in Dundee, Scotland.

A recent Swedish study entitled: "*How children perceive the acoustic environment of their school*" (Branstrom, Vigertsson et al, 2017) is one such project. Using an evidence-based questionnaire, they reported children aged 9-13 years found crowded spaces to be the most challenging as the children themselves created the majority of the noise within the classroom. Traffic noise and the teachers in adjacent classrooms. Responses to ambient background noise levels were dependant on the activity at the time. The children reported increased levels of annoyance when the tasks involved verbal processing. It is quite conceivable that some of the difficulties caused by intrusive noise in MLE may be attributed to what researchers have termed the "irrelevant speech effect" which is largely attributable to the distracting effect of background conversations (Banbury & Berry, 2005). This phenomenon is also a common cause of frustration and difficulties concentrating in open plan offices (Banbury & Berry, 2005).

Additionally, children with special needs appeared to report that they are more susceptible to noise than the normal children. Similar findings were reported in a cohort of special needs adolescents aged from 11-16 years (Connolly, Dockrell, Shield, Conetta and Cox; 2014)

The majority of acoustical measurements reported in this current investigation show that many acoustical environments, both MLE and TRAD were sub-standard in relation to the recommended national and international standards. In view of this, it would be useful for future research to be conducted into the practical and financial feasibility of refurbishing existing NZ classrooms in order to improve their acoustical performance, specifically to reduce the ambient noise and RT. Some preliminary work has been undertaken by Shield & Conetta in the UK which suggests that the two most effective measures to improve the acoustics in open classrooms include managing the amount of glass and the height of spaces. Lowering the RT, was most effectively accomplished by installing a suspended ceiling which reduced the total volume of the room considerably and hence was more successful than simply applying absorptive acoustic tiles to the existing ceiling. However, retro-fitting of absorptive material to the ceiling proved better at reducing the RT than the addition of carpet alone. Ideally, implementing both of these modifications would reduce the deleterious effects of noise, and long RT times thus improving the speech intelligibility in MLE (Shield & Conetta, 2015)

Another study has undertaken research in this area with a particular focus on Teachers' perception of noise exposure and equipment disruption as well as their vocal health and overall well-being (Kristiansen, Lund, Persson, Challi, Lindskov, Nielsen, Toftum, 2016). It would be useful to perform similar interventions in NZ classrooms with a focus on the subjective improvements perceived by both teachers and children using these spaces.

Given that some MLE appear to have less than desirable acoustic properties future research endeavours ought to focus on mitigating these detrimental features. Another option, which does not involve architectural modification is through the use of sound field amplification. This approach requires the provision of dynamic speakers within a room where a teacher's voice is amplified uniformly to the whole class as a consequence of a clip-on microphone with wireless transmission to the speakers. This technology is known to improve the signal-to-noise ratio by approximately 8-10dB in high background noise situations. Previous research in traditional classrooms has shown excellent benefits (da Cruz et al., 2016; Dockrell, & Shield, 2012; McLaren & Humphries, 2009; Smaldino, & Crandell, 2000). It remains unclear whether this technology would prove efficacious in those MLE spaces which are acoustically underperforming. Judicious use by teachers to gain the attention of children could well prevent some vocal strain for those teaching in MLE in the presence of large numbers of children. Suitable uses could be to gain the attention, or instruct a specific cluster of children. Likewise, when combined classes within one MLE are involved in a shared activity such as listening to a film. However, a substantial caveat to the provision of SFA in MLE is the significant risk of just increasing the overall noise levels within the teaching space (Mealings et al, 2016) Whilst the provision of SFA ought not to be viewed as a substitute for sub-optimal acoustics, it may be a feasible option to retro-fit these systems in some MLE to improve their acoustic performance.

A good signal to noise ratio is considered to be +15 decibels (ASHA, 2000; Mealings et al, 2016; Nelson et al, 2000), this is critically important for young children between the ages of 5-10 years who are still developing speech and language (Dockrell & Shield, 2012; Madell, & Flexer, 2014). Personal FM systems are known to favourably increase the signal to noise ratio, and they have been used successfully for some time now to help some children with hearing loss. Less is known about the positive impact of these systems for children who may not appear to have a hearing loss, but who struggle with other aspects of learning such as attention and behaviour. Such research could be particularly helpful in gaining much needed increase in government funding for permanent or trials of personal FM systems for children with confirmed, or suspected APD, and or learning and behaviour issues. This is an area which is noticeably under-resourced, and under-funded within the NZ education system. It is the view of this author, that failure to provide adequate technical support in the form of personal FM systems has the potential to have life-long negative consequences for children exhibiting such difficulties. Research seems to acknowledge that increasing the numbers of children in a space is likely to subsequently raise the background noise levels due to the Lombard/café effect (Whitlock, 2016) One acoustic consultant remarked (in personal correspondence with the researcher) that the "government is committed to the concept of MLE, - the cat is out of the bag so to speak". Hence, the necessity of providing more FM systems, along with additional support may be one of the un-intended costs/consequences of the new pedagogical, and acoustic environments synonymous with the background noise generated by the large numbers of children taught together in MLE.

Future research could also examine the feasibility of simple solutions such as using “traffic light” indicators to monitor the noise levels in various parts of the MLE, to assess whether the presence of these devices can reduce the propensity for sound levels to increase due to the Lombard and Café effects. One unit created in NZ called the “Safe Sound Indicator” is based on the traffic light colour coding system to indicate noise levels. It evolved from an idea by a NZ school girl, Jamie Fenton, and is endorsed by the National Foundation for the Deaf. The systems are widely used in pre-schools and kindergartens to help manage noise levels. Instrumentation firm, Bruel & Kjaer have also developed a similar indicator called the “SoundEar 2000”.

Many of these indicators have been developed into simple customisable apps which can be used on mobile phones or i-pads, and projected up onto screens on walls. Additionally, a rewards system can be established with students when the noise levels remain within the pre-set parameters. Some examples include, “Silent light” (from iOS app store) is one such example, it was designed by teachers for teachers. “Talk light” is another example. Several other free apps are “Classcraft Volume Meter” / “Too noisy”/ “Bouncy Balls”. Whitlock and Dodd, have suggested these classroom meters should be optimised to minimise the Lombard and Café Effects. Their research indicates the settings for quiet activities should be at approximately forty dB(A) ambient noise as this causes an increase in voice levels of approximately three dB(A) which is barely perceptible, and as such does not instigate the Lombard Effect. They also advise setting the warning levels for louder activities at around sixty-sixty five dB(A) (Whitlock & Dodd, 2008)

The National Acoustic Laboratory in Australia, have also developed the "Sound-Out" App for Classrooms" which enables teachers and others to simply and cost effectively assess the acoustics of their room, in addition, the space could be re-tested after some acoustical modifications to evaluate their efficacy.

Another potential research area could involve surveying schools nationwide, to evaluate the prevalence of MLE in public schools versus the number in private schools, and relate this data to the decile rating of schools. Allied to this research is the need for data around the public perception of MLE's. Opinions from parents, teachers and principals appear to be rigorously divided between support and condemnation. (Gerritsen, 2015; McCance, 2015)

An education campaign needs to be instituted which raises awareness amongst teachers, principals, and school boards of trustees, and the management team about the enormous significance of classroom acoustics on learning. A particular emphasis needs to be placed on the set up and use of these spaces, even with good acoustic design the outcomes will be poor if they are used inappropriately. Future research directions need to focus on enabling teachers, for, without adequate training the consequences can be dire. One acoustician reported that a school in Denmark lost thirty percent of its staff following the implementation of MLE (Whitlock, 2012). This indicates the need for in service training programmes for experienced educators. Courses also need to be instituted at Teachers Training Colleges to prepare young teachers to manage their classes within these flexible environments, and to utilise the various break out spaces available to them.

Given the essentially prohibitive cost to schools of having the acoustics of buildings assessed, an alternative may be to use the customised NAL 'SoundOut' App. It may be an efficacious, efficient, simple, and extremely cost effective means of collecting classroom acoustical data on a large scale. One of the features of the app is the provision of remedial solutions to address the particular set of acoustical parameters which are measured. Therefore, once this data is compiled, it may provide useful empirical evidence to present to individual school boards to support the provision of additional funding for acoustic treatments to substandard rooms. Or perhaps schools could forward their data to the MoE (as the technical owners of these open-plan buildings) again to secure supplementary funding to increase the acoustic performance of these spaces. Given the wide range of building designs across the country, each classroom is likely to have a unique set of fittings and bespoke materials, which will influence their overall acoustics, hence it is vital that each room is evaluated on a case-by-case basis.

Additionally, the ‘SoundOut’ App can be employed subsequent to any modifications to verify the efficacy of these treatments. One of the real benefits of this simple app. is the ability for data to be collected nationwide on a large scale across a wide variety of classroom spaces. Something which is pointedly lacking in the available research which tends to focus on just a few classrooms at a time. Once this research has been undertaken, it may be useful for certain governing bodies within Aotearoa/NZ to ensure the current DQLS acoustical guidelines for MLE are legally mandated to ensure speech perception is not compromised for young learners.

8.2 Final Thoughts

This study has endeavoured to make a small contribution to the body of literature concerning classroom acoustics. It is to be hoped that future research will continue to focus on the acoustic features of classrooms, especially, MLE, given the MoE determination to substantially increase the number of these teaching facilities throughout NZ schools. If children in state education facilities must be taught in barn-like structures in a free-range manner then, it would be preferable for **ALL** MLE to undergo rigorous architectural modelling at the planning stage which includes the acoustic parameters of these buildings. Specifically aiming to ensure materials and design characteristics create ‘optimum’ rather than just ‘acceptable’ acoustic environments for both teaching learning. It would be preferable for the MoE DQLSv2 (2016) document on acoustical requirements to become a legal requirement rather than its current voluntary “guideline” status, which seems to allow for enormous and often undesirable variation from the recommended “guidelines”.

Furthermore, while classroom acoustics per se may be considered outside the ‘scope of practice’ for many in the audiology profession, it is probably time this position was reconsidered. As the specialists who are often associated with the diagnoses and re-habilitation of children with hearing/listening difficulties, it is imperative that the profession as a whole becomes more pro-active. Preferably at a level of involvement which includes both an increased awareness of the issues around classroom acoustics, but also an increased level of activism in regard to the remediation of poor classroom acoustics. Audiologists are in the unique position to act as facilitators between children, parents, teachers, principals, school managers, the general public and acoustical design engineers. The bottom line is that fiscal frugality and the appeal of fashionable architecture ought not to supersede functional acoustics.

“We put children in classrooms where they can’t hear,

but

we’d never put kids in a classroom with the lights turned off”

(Lubman, 1997)

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APPENDIX A: ***ETHICAL APPROVAL***

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Rebecca Robinson
Telephone: +64 03 369 4588, Extn 94588
Email: human-ethics@canterbury.ac.nz

Ref: 2018/03/ERHEC-LR

23 May 2018

Jan-Maree McKinlay Communication Disorders UNIVERSITY OF CANTERBURY

Dear Jan-Maree

Thank you for submitting your low risk application to the Educational Research Human Ethics Committee for your research proposal titled “"Echoes in Education" - Classroom Acoustics in Traditional and Modern Learning Environments in NZ”.

I am pleased to advise that this application has been reviewed and I confirm support of the School’s approval for this project.

With best wishes for your project.
Yours sincerely

pp

R. Robinson

Dr Patrick Shepherd

Chair Educational Research Human Ethics Committee

Please note that ethical approval relates only to the ethical elements of the relationship between the researcher, research participants and other stakeholders. The granting of approval by the Educational Research Human Ethics Committee should not be interpreted as comment on the methodology, legality, value or any other matters relating to this research.
FES

APPENDIX B: *RECRUITMENT*

B.1 Initial recruitment e-mail (page 1 of 2)

Department of Communication Disorders
UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND
University of Canterbury
Telephone (0274) 887 549
Email jan.Mckinlay@pg.canterbury.ac.nz

INFORMATION SHEET

Study: "Echoes in Education": Classroom Acoustics in Traditional, and Modern Learning Environments

Dear Principal/Teacher,

This letter is to inform you about a study of classroom acoustics and to request access to your school to undertake acoustic testing.

Jan McKinlay is currently studying for a Masters in Clinical Audiology at the University of Canterbury. Part of the course requires a research thesis. The aim of the study is to collect valuable information regarding the acoustics in Traditional, and Modern Learning Environments that educate children with normal and impaired hearing. This information will help teachers and building designers to ensure current and future classrooms are delivering the best acoustic environments for learning and teaching as recommended by the Ministry of Education in their 2016 document "Designing quality learning spaces" v2.

There is a lack of studies measuring the noise conditions in New Zealand Schools. In particular, few have been carried out in Modern Learning Environments. Most of the Studies have come from overseas, where classrooms conditions and teaching methods are different from New Zealand. The studies that have been done in New Zealand schools were done over 15 years ago, since this time classrooms and teaching spaces have changed in a number of ways. Your assistance will provide valuable information which will contribute to "real-world" knowledge about the current listening environments in New Zealand primary schools.

High noise levels and excessive reverberation times in classrooms make the already difficult task of learning and teaching even harder particularly for children with a hearing loss. Numerous studies have shown they perform significantly worse in these conditions compared to children with normal hearing.

Elevated noise in a classroom also forces the teacher to raise their voice, which can lead to premature tiredness and frustration with their students. Furthermore, Teachers overseas have been shown to have a higher incidence of vocal difficulties than do the general population.

Ambient noise, background noise and reverberation times and speech transmission scores are used to describe acoustical performance of classrooms. I will be taking these measurements using an i-pad. The four measurements which will be taken are outlined below. (Total duration around 30 minutes of classroom time.)

1 Ambient Noise Levels will be taken during the children's lunch break. These noise levels represent a time when the classroom is unoccupied but ready for occupancy meaning that all the equipment in the room (computers, air- conditioners etc) that is used on a typical school day is turned on.
2 Background Noise Levels will be taken following the lunch break. Background noise levels are the levels in a classroom during normal learning activities specifically reading, writing, or colouring-in (approximately 15 minutes)
3 Reverberation Times will be recorded when the room is unoccupied. Reverberation time is the time it takes for a sound to fade away in a room. The sound source that will be used is the sound of a balloon popping.
4 Speech Transmission Index Score will automatically be calculated following the measuring of BNL and RT.

All the information collected from each school will be kept confidential. The names of both the school and any staff members will be removed from all documentation. The results of the project may be published, but you may be assured of the complete confidentiality of data gathered in this study. Information you provide will be confidential, with no information that could identify you or your school will be used in any study reports or my thesis. To ensure anonymity and confidentiality, all data will be kept in a locked filing cabinet and in password-protected computer files. This data will be destroyed five years after the study is completed. A thesis is a public document and will be available through the UC Library.

Participation is voluntary and you have the right to withdraw your school's participation at any stage without penalty. You may ask for your raw data to be returned to you or destroyed at any point. If you withdraw, I will remove information relating to your school. However, once analysis of raw data starts on [*1 July 2018*], it will become increasingly difficult to remove the influence of data on the results.
Please indicate to the researcher on the consent form if you would like to receive a copy of the summary of results of the project.
If there are any questions you need answered, feel free to contact :-

Jan McKinlay on (0274) 887 549 or jan.Mckinlay@pg.canterbury.ac.nz or
Dr Dean Sutherland (Supervisor) (03) 369 5090 dean.sutherland@canterbury.ac.nz
If you agree to participate in the study please email me at or jan.Mckinlay@pg.canterbury.ac.nz. I will then be in touch to arrange a date and time to visit your school.

This project has been reviewed and approved by the University of Canterbury Educational Research Human Ethics Committee, and participants should address any complaints to The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch. (human-ethics@canterbury.ac.nz)

Sincerely,

Jan McKinlay

Jan McKinlay, Master of Audiology student

B.2 Research information sheet

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Department of Communication Disorders
University of Canterbury
Telephone (0274) 887 549
Email jan.Mckinlay@pg.canterbury.ac.nz

INFORMATION SHEET

Study title: "Echoes in Education": Classroom Acoustics in Traditional, and Modern Learning Environments

Dear Parent/Guardian

My name is Jan McKinlay and I am currently studying towards a Masters in Clinical Audiology at the University of Canterbury. Part of the course requires me to complete a study and write a research thesis. The aim of the study is to collect information about the acoustics (sound properties) in Traditional classrooms and Modern Learning Environments that educate children with normal and impaired hearing. This information will help teachers and building designers to ensure current and future classrooms are delivering the best acoustic environments for learning and teaching as recommended by the Ministry of Education in their 2016 document "Designing quality learning spaces".

Ambient noise, background noise and reverberation times and speech transmission scores are used to describe acoustical performance of classrooms. I will be taking these measurements using an i-pad. The four measurements which will be taken are outlined below. (Total duration around 30 minutes of classroom time.)

1. Ambient Noise Levels will be taken in the morning before school starts. These noise levels represent a time when the classroom is unoccupied but ready for occupancy meaning that all the equipment in the room (computers, air- conditioners) that is used on a typical school day is turned on.
2. Background Noise Levels will be taken following the during class time. Background noise levels are the levels in a classroom during normal learning activities specifically reading, writing, or colouring-in (approximately 15 minutes)
3. Reverberation Times will be recorded when the room is unoccupied. Reverberation time is the time it takes for a sound to fade away in a room. The sound source that will be used is the sound of a balloon popping.
4. Speech Transmission Index Score will automatically be calculated following the measuring of BNL and RT.

All the information collected from each school will be kept confidential. The names of both the school and any staff members will be removed from all documentation.
This project has been reviewed and approved by the University of Canterbury Human Ethics Committee, and participants should address any complaints to The Chair, Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)

If there are any questions you need answered, feel free to contact :-

Jan McKinlay on (0274) 887 549 or jan.Mckinlay@pg.canterbury.ac.nz or
Dr Dean Sutherland (Supervisor) (03) 369 5090 dean.sutherland@canterbury.ac.nz

Yours sincerely

Jan McKinlay (Master of Audiology Student)

B.3 Research information, Adult consent form

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Department of Communication Disorders
Telephone: +64 3 [0274 887549]
Email: jan.Mckinlay@pg.canterbury.ac.nz **Study title:**

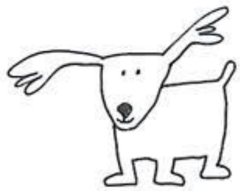
"Echoes in Education"- Classroom Acoustics in Traditional, and Modern Learning Environments

(Kindly, indicate MLE, or traditional, or both, + number of pupils in this teaching space)
Consent Form for ....(name of primary school]
Room to be tested =(MLE) ....max # of children in this space =.............
Room to be tested =(TRAD)...................................max # of children in this space =.............

- ☐ I have been given a full explanation of this project and have had the opportunity to ask questions.
- ☐ I understand what is required of me if I agree to take part in the research.
- ☐ I understand that participation is voluntary and I may withdraw at any time without penalty. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable.
- ☐ I understand that any information or opinions I provide will be kept confidential to the researcher and supervisor and that any published or reported results will not identify the participants or their school. I understand that a thesis is a public document and will be available through the UC Library
- ☐ I understand that all data collected for the study will be kept in a secure facilities and/or in password protected electronic form and will be destroyed after five years
- ☐ I understand the risks associated with taking part and how they will be managed. I understand that I can contact the researcher [**Jan McKinlay** on (0274) 887 549 or jan.Mckinlay@pg.canterbury.ac.nz] or supervisor **Dr Dean Sutherland** on (03) 369 5090 dean.sutherland@canterbury.ac.] for further information. If I have any complaints, I can contact the Chair of the University of Canterbury Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)
- ☐ I would like a summary of the results of the project.
- ☐ By signing below, I agree to participate in this research project.

Principal/Teacher:____
Signed:__________________________Date:____
Email address *(for report of findings, if desired)*:____________________________________
Kindly return this consent form to: jan.Mckinlay@pg.canterbury.ac.nz

B.4 Research information, and consent for children



INFORMATION FOR CHILDREN

This project is about sound and how important it is to have classrooms which are well built so you can hear well when you are learning.

Ms McKinlay will be using a microphone and a computer to measure how loud the sound is in your classroom, and how sound bounces around the room at different times when you are doing activities. at your desk or on the mat, or at the computer.

The topic your teacher will be talking about will be sound and hearing and how amazing our ears are. You just need to listen to the teacher and join in when they ask you to, there may will also be some group discussions.

At the end we will pop some balloons to see how much sound bounces around in your classroom.

The project that Ms McKinlay wants to do about sound and hearing has been explained to me. I know I don't have to be a part of it if I don't want to. If I have any questions I can ask my teacher or Ms McKinlay.

- I am happy to be part of the project so I have coloured in the thumbs up picture

OR

- I don't want to be part of the project so I have coloured in the thumbs down picture

My name: ____

Please give this back to your teacher now.

APPENDIX C: *CLASSROOM INFORMATION SHEETS*

C.1 ROOM 1 MLE 1

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 1
DECILE RATING: 10
TYPE OF CLASSROOM –MLE

1. Number of children in classroom 2 X 20 (40 in total) & Age 5,6
2. Classroom measurements L=9.54m W=7.25m H=3.4m V=235.2m^3
3. Additional Info – x2 old refurbished prefabs joined together, on a concrete slab
4. Building age 30-40 ? yrs
5. High ceiling Y/N
6. Carpeted floors Y/N
7. Pin up boards Y/N
8. Curtains Y/N
9. Air Conditioning unit Y/N
10. Projector Y/N
11. Bare walls Y/N
12. Large Windows Y/N
13. Building Material –Fibrolite? Y/N
14. Fans Y/N
15. Open door to adjacent classroom Y/N
16. Concertina wall or partition to another room Y/N
17. Artwork suspended from ceiling Y/N
18. Child with hearing impairment Y/N
19. FM system in use (individual or classroom) Y/N
20. Building is prefab (raised above ground on supports) – noisy under footfall Y/N
21. Acoustically treated ceiling Y/N (30 %)
22. Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 42.9 RT = 0.5

Bkgd. Noise x 3 = 64.8 STI = 0.57

C.2 ROOM 2 MLE 2

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 2
DECILE RATING: 10
TYPE OF CLASSROOM MLE

1. Number of children in classroom 3 X 22 (66 in total) & Age 5,6
2. Classroom measurements L=16.4m W=15.24m H=3.5 m V=885.2m^3
3. Additional Info –
4. Building age 4 yrs
5. High ceiling Y/N
6. Carpeted floors Y/N
7. Pin up boards Y/N
8. Curtains Y/N
9. Air Conditioning unit Y/N
10. Projector Y/N
11. Bare walls Y/N
12. Large Windows Y/N
13. Building Material –modern -linea weatherboard Y/N
14. Fans Y/N
15. Open door (or folding) to adjacent classroom Y/N
16. Concertina wall or partition to another room Solid double glazed sliding door Y/N
17. Artwork suspended from ceiling Y/N
18. Child with hearing impairment Y/N
19. FM system in use (individual or classroom) Y/N
20. Building is prefab (raised above ground on supports) – noisy under footfall Y/N
21. Acoustically treated ceiling Y/N (100 %)
22. Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 50.3 RT = 0.42

Bkgd. Noise x 3 = 53.6 STI = 0.68

C.3 ROOM 3 MLE 3

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 3
DECILE RATING: 10
TYPE OF CLASSROOM MLE

1. Number of children in classroom 3 X 23 (70 in total) & Age 5,6
2. Classroom measurements L=20.87m W=15.22m H=3.5 m V=1,112m^3
3. Additional Info –
4. Building age 4 yrs
5. High ceiling Y/N
6. Carpeted floors Y/N
7. Pin up boards Y/N
8. Curtains Y/N
9. Air Conditioning unit Y/N
10. Projector Y/N
11. Bare walls Y/N
12. Large Windows Y/N
13. Building Material – modern -linea weatherboard Y/N
14. Fans Y/N
15. Open door (or folding) to adjacent classroom Solid double glazed sliding door
16. Concertina wall or partition to another room Y/N
17. Artwork suspended from ceiling Y/N
18. Child with hearing impairment Y/N
19. FM system in use (individual or classroom) Y/N
20. Building is prefab (raised above ground on supports) – noisy under footfall Y/N
21. Acoustically treated ceiling Y/N (100 %)
22. Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 37.8 RT = 0.41

Bkgd. Noise x 3 = 54.9 STI = 0.65

C.4 ROOM 4 MLE 4

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 4
DECILE RATING: 10
TYPE OF CLASSROOM MLE

1. Number of children in classroom 3 X 29 (87 in total) & Age 10,11,12
2. Classroom measurements L=18.00m W=10.07m H=3.5 m V=638m^3
3. Additional Info – quite a few international students (ESOL)
4. Building age 4 yrs
5. High ceiling Y/N
6. Carpeted floors Y/N
7. Pin up boards Y/N
8. Curtains Y/N
9. Air Conditioning unit Y/N
10. Projector Y/N
11. Bare walls Y/N
12. Large Windows Y/N
13. Building Material – modern -linea weatherboard Y/N
14. Fans Y/N
15. Open door (or folding) to adjacent classroom Solid double glazed sliding door
16. Concertina wall or partition to another room Y/N
17. Artwork suspended from ceiling Y/N
18. Child with hearing impairment Y/N
19. FM system in use (individual or classroom) Y/N
20. Building is prefab (raised above ground on supports) – noisy under footfall Y/N
21. Acoustically treated ceiling Y/N (100 %)
22. Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 38.9 RT = 0.39

Bkgd. Noise x 3 = 52.6 STI = 0.73

C.5 ROOM 5 MLE 5

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 5
DECILE RATING: 10
TYPE OF CLASSROOM MLE

1. Number of children in classroom 3 X 29 (87 in total) & Age 10,11,12
2. Classroom measurements L=18.00m W=10.07m H=3.5 m V=638m^3
3. Additional Info – teachers attempted a lot of "shushing, shhh shhhh, shhh"
4. Building age 4 yrs
5. High ceiling Y/N
6. Carpeted floors Y/N
7. Pin up boards Y/N
8. Curtains Y/N
9. Air Conditioning unit Y/N
10. Projector Y/N
11. Bare walls Y/N
12. Large Windows Y/N
13. Building Material – modern -linea weatherboard Y/N
14. Fans Y/N
15. Open door (or folding) to adjacent classroom Solid double glazed sliding door
16. Concertina wall or partition to another room Y/N
17. Artwork suspended from ceiling Y/N
18. Child with hearing impairment Y/N
19. FM system in use (individual or classroom) Y/N
20. Building is prefab (raised above ground on supports) – noisy under footfall Y/N
21. Acoustically treated ceiling Y/N (100 %)
22. Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 41.4 RT = 0.43

Bkgd. Noise x 3 = 57.4 STI = 0.56

C.6 ROOM 6 MLE 6

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 6
DECILE RATING: 10
TYPE OF CLASSROOM MLE

1. Number of children in classroom 3 X 29 (89 in total) & Age 8,9
2. Classroom measurements L=18.00m W=10.07m H=3.5 m $V=638m^3$
3. Additional Info –
4. Building age 4 yrs
5. High ceiling Y/N
6. Carpeted floors Y/N
7. Pin up boards Y/N
8. Curtains Y/N
9. Air Conditioning unit Y/N
10. Projector Y/N
11. Bare walls Y/N
12. Large Windows Y/N
13. Building Material – modern -linea weatherboard Y/N
14. Fans Y/N
15. Open door (or folding) to adjacent classroom Solid double glazed sliding door
16. Concertina wall or partition to another room Y/N
17. Artwork suspended from ceiling Y/N
18. Child with hearing impairment Y/N
19. FM system in use (individual or classroom) Y/N
20. Building is prefab (raised above ground on supports) – noisy under footfall Y/N
21. Acoustically treated ceiling Y/N (100 %)
22. Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 40.0 RT = 0.42

Bkgd. Noise x 3 = 56.7 STI = 0.60

C.7 ROOM 7 MLE 7

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 7
DECILE RATING: 6
TYPE OF CLASSROOM MLE

1 Number of children in classroom 2 X 29 (59 in total) & Age 5,6
2 Classroom measurements L=14.46m W=9.01m H=3.47 m V=451.74m^3
3 Additional Info –
4 Building age 100 yrs
5 High ceiling Y/N
6 Carpeted floors Y/N
7 Pin up boards Y/N
8 Curtains Y/N
9 Air Conditioning unit Y/N
10 Projector Y/N
11 Bare walls Y/N
12 Large Windows Y/N
13 Building Material –wooden weatherboard on solid concrete foundation Y/N
14 Fans Y/N
15 Open door (or folding) to adjacent classroom Solid double glazed sliding door
16 Concertina wall or Left=several partitions within room all acoustically treated Y/N
17 Artwork suspended from ceiling Y/N
18 Child with hearing impairment Y/N
19 FM system in use (individual or classroom) Y/N
20 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
21 Acoustically treated ceiling Y/N Left photo (70 %) Right photo (100 %)
22 Acoustically treated walls Y/N Left photo (70 %) Right photo (100 %)

Amb. Noise x 1 = 37.8 RT = 0.41

Bkgd. Noise x 3 = 46.2 STI = 0.73

C.8 ROOM 8 MLE 8

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 8
DECILE RATING: 6
TYPE OF CLASSROOM MLE

1. Number of children in classroom 2 X 27 (54 in total) & Age 8,9,10
2. Classroom measurements L=14.73m W=12.43m H=3.58 m V=655.47m^3
3. Classroom photo
4. Additional Info –
5. Building age 100 yrs
6. High ceiling Y/N
7. Carpeted floors Y/N
8. Pin up boards Y/N
9. Curtains Y/N
10. Air Conditioning unit Y/N
11. Projector Y/N
12. Bare walls Y/N
13. Large Windows Y/N
14. Building Material –wooden weatherboard on solid concrete foundation Y/N
15. Fans Y/N
16. Open door (or folding) to adjacent classroom Solid double glazed sliding door
17. Concertina wall or partition to another room Y/N
18. Artwork suspended from ceiling Y/N
19. Child with hearing impairment Y/N
20. FM system in use (individual or classroom) Y/N
21. Building is prefab (raised above ground on supports) – noisy under footfall Y/N
22. Acoustically treated ceiling Y/N (100 %)
23. Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 34.5 RT = 0.46

Bkgd. Noise x 3 = 43.4 STI = 0.78

C.9 ROOM 9 MLE 9

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 9
DECILE RATING: 6
TYPE OF CLASSROOM MLE

1 Number of children in classroom 2 X 22 (45 in total) & Age 5,6,7,8
2 Classroom measurements L=17.42m W=7.28m H=3.54 m V=448.67m^3
3 Classroom photo
4 Additional Info –
5 Building age 100 yrs
6 High ceiling Y/N
7 Carpeted floors Y/N
8 Pin up boards Y/N
9 Curtains Y/N
10 Air Conditioning unit Y/N
11 Projector Y/N
12 Bare walls Y/N
13 Large Windows Y/N
14 Building Material –wooden weatherboard on solid concrete foundation Y/N
15 Fans Y/N
16 Open door (or folding) to adjacent classroom Solid double glazed sliding door
17 Concertina wall or floor-ceiling partitions to within room = half walls Y/N
18 Artwork suspended from ceiling Y/N
19 Child with hearing impairment Y/N
20 FM system in use (individual or classroom) Y/N
21 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
22 Acoustically treated ceiling Y/N (100 %)
23 Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 37.1 RT = 0.36

Bkgd. Noise x 3 = 53.5 STI = 0.66

C.10 ROOM 10 MLE 10

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 10
DECILE RATING: 5
TYPE OF CLASSROOM MLE

1 Number of children in classroom (36 in total) & Age 5,6,
2 Classroom measurements L=23.43m W=7.30m H=3.41 m V=583.48m^3
3 Classroom photo
4 Additional Info – x2 old prefabs. joined
5 Building age 50+ yrs
6 High ceiling Y/N
7 Carpeted floors very thin, & coverage = about 2/3, rest = lino Y/N
8 Pin up boards Y/N
9 Curtains Y/N
10 Air Conditioning unit Y/N
11 Projector Y/N
12 Bare walls Y/N
13 Large Windows Y/N single glazed, + louvres, planes, birds, audible when closed
14 Building Material – fibrolite ? Y/N
15 Fans Y/N
16 Open door (or folding) to adjacent classroom no door or divider of any sort
17 Toilet facilities centered in middle of this classroom !!!
18 Concertina wall or floor-ceiling partitions to within room = half walls Y/N
19 Artwork suspended from ceiling Y/N
20 Child with hearing impairment Y/N – x1 CHL
21 FM system in use (individual or classroom) Y/N
22 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
23 Acoustically treated ceiling Y/N very old painted pinex? Low co-efficent ? (0 ? %)
24 Acoustically treated walls Y/N modern absorbent material (80 %)

Amb. Noise x 1 = 48 RT = 0.65

Bkgd. Noise x 3 = 69.3 STI = 0.19

C.11 ROOM 11 MLE 11

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 11

DECILE RATING: 10

TYPE OF CLASSROOM MLE

1 Number of children in classroom (23 in total) & Age 9,10,11
2 Classroom measurements L=8.28m W=7.28m H=3.61 m V=217.72m^3
3 Additional Info –
4 Building age 3 yrs
5 High ceiling Y/N
6 Carpeted floors Y/N
7 Pin up boards Y/N
8 Curtains Y/N
9 Air Conditioning unit Y/N
10 Projector Y/N
11 Bare walls Y/N
12 Large Windows Y/N (glazing on x3 sides of this room including sliding door)
13 Building Material – modern -linea weatherboard Y/N
14 Fans Y/N
15 Open door (or folding) to adjacent classroom Solid double glazed sliding door
16 Concertina wall or partition to another room Y/N
17 Artwork suspended from ceiling Y/N
18 Child with hearing impairment Y/N
19 FM system in use (individual or classroom) Y/N
20 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
21 Acoustically treated ceiling Y/N (100 %)
22 Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 33.5 RT = 0.56

Bkgd. Noise x 3 = 45 STI = 0.70

C.12 ROOM 12 TRAD 1
ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 12
DECILE RATING: 6
TYPE OF CLASSROOM TRAD

1 Number of children in classroom (30 in total) & Age 11,12,13
2 Classroom measurements L=8.28m W=7.28m H=3.61 m V=217.72m^3
3 Classroom photo
4 Additional Info –
5 Building age 50+ yrs
6 High ceiling Y/N
7 Carpeted floors Y/N
8 Pin up boards Y/N
9 Curtains Y/N
10 Air Conditioning unit Y/N
11 Projector Y/N
12 Bare walls Y/N
13 Large Windows Y/N (along one wall only)
14 Building Material – solid brick exterior Y/N
15 Fans Y/N
16 Open door (or folding) to adjacent classroom Y/N
17 Concertina wall or partition to another room Y/N
18 Artwork suspended from ceiling Y/N
19 Child with hearing impairment Y/N x1 CI
20 FM system in use (individual or classroom) Y/N
21 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
22 Acoustically treated ceiling Y/N (0 %)
23 Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 38.2 RT = 0.54

Bkgd. Noise x 3 = 59 STI = 0.51

C. 13 ROOM 13 TRAD 2

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 13
DECILE RATING: 6
TYPE OF CLASSROOM TRAD

1 Number of children in classroom (23 in total) & Age 7,8,9
2 Classroom measurements L=7.97m W=7.41m H=3.64 m V=214.6m^3
3 Additional Info – Old furniture (4 legged chairs)
4 Building age 50+ yrs
5 High ceiling Y/N
6 Carpeted floors Y/N
7 Pin up boards Y/N
8 Curtains Y/N
9 Air Conditioning unit Y/N
10 Projector Y/N
11 Bare walls Y/N
12 Large Windows Y/N (along one wall only)
13 Building Material – solid brick exterior Y/N
14 Fans Y/N
15 Open door (or folding) to adjacent classroom Y/N
16 Concertina wall or partition to another room Y/N
17 Artwork suspended from ceiling Y/N
18 Child with hearing impairment Y/N
19 FM system in use (individual or classroom) Y/N
20 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
21 Acoustically treated ceiling Y/N (0 %)
22 Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 40.2 RT = 0.60

Bkgd. Noise x 3 = 50.5 STI = 0.62

C.14 ROOM 14 TRAD 3

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 13
DECILE RATING: 6
TYPE OF CLASSROOM TRAD

1 Number of children in classroom (22 in total) & Age 7,8,9
2 Classroom measurements L=8.77m W=6.78m H=3.42 m V=203.15m^3
3 Classroom photo
4 Additional Info – Old furniture (4 legged chairs) Stand-alone building
5 Building age 20+ yrs
6 High ceiling Y/N
7 Carpeted floors Y/N
8 Pin up boards Y/N
9 Curtains Y/N
10 Air Conditioning unit Y/N
11 Projector Y/N
12 Bare walls Y/N
13 Large Windows Y/N (1/2 height along two walls)
14 Building Material – fibrolite Y/N
15 Fans Y/N
16 Open door (or folding) to adjacent classroom Y/N (door to resource room)
17 Concertina wall or partition to another room Y/N
18 Artwork suspended from ceiling Y/N
19 Child with hearing impairment Y/N
20 FM system in use (individual or classroom) Y/N
21 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
22 Acoustically treated ceiling Y/N old material (0 %)
23 Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 34.7 RT = 0.63

Bkgd. Noise x 3 = 53.3 STI = 0.62

C.15 ROOM 15 TRAD 4
ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 15
DECILE RATING: 6
TYPE OF CLASSROOM TRAD

1 Number of children in classroom (30 in total) & Age 5,6
2 Classroom measurements L=8.56m W=7.20m H=3.41 m V=209.99m^3
3 Classroom photo
4 Additional Info – ceiling treatment = old, low co-efficient
5 Building age 20+ yrs
6 High ceiling Y/N
7 Carpeted floors Y/N
8 Pin up boards Y/N
9 Curtains Y/N
10 Air Conditioning unit Y/N
11 Projector Y/N
12 Bare walls Y/N
13 Large Windows Y/N (1/2 height along two walls)
14 Building Material – fibrolite Y/N
15 Fans Y/N
16 Open door (or folding) to adjacent classroom Y/N
17 Concertina wall or partition to another room Y/N
18 Artwork suspended from ceiling Y/N
19 Child with hearing impairment Y/N x2 CHL
20 FM system in use (individual or classroom) Y/N
21 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
22 Acoustically treated ceiling Y/N old material (0 %)
23 Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 43.1 RT = 0.48

Bkgd. Noise x 3 = 68.7 STI = 0.24

C.16 ROOM 16 TRAD 5
ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 16
DECILE RATING: 5
TYPE OF CLASSROOM TRAD

1 Number of children in classroom (27 in total) & Age 7,8,9
2 Classroom measurements L=9.57m W=6.78m H=3.39 m V=218m^3
3 Classroom photo
4 Additional Info –
5 Building age 20+ yrs
6 High ceiling Y/N
7 Carpeted floors Y/N
8 Pin up boards Y/N
9 Curtains Y/N
10 Air Conditioning unit Y/N
11 Projector Y/N
12 Bare walls Y/N
13 Large Windows Y/N (new SINGLE GLAZED; 1 wall=1/2 height, other= ¼ height)
14 Building Material – fibrolite Y/N
15 Fans Y/N
16 Open door (or folding) to adjacent classroom Y/N
17 Concertina wall or partition to another room Y/N
18 Artwork suspended from ceiling Y/N
19 Child with hearing impairment Y/N
20 FM system in use (individual or classroom) Y/N
21 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
22 Acoustically treated ceiling Y/N mix of old material (40 % modern panels)
23 Acoustically treated walls Y/N (80 %)

Amb. Noise x 1 = 37.6 RT = 0.47

Bkgd. Noise x 3 = 52.8 STI = 0.66

C.17 ROOM 17 TRAD 6
ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 17
DECILE RATING: 5
TYPE OF CLASSROOM TRAD

1 Number of children in classroom (28 in total) & Age 7,8,9
2 Classroom measurements L=9.57m W=6.78m H=3.39 m V=218m^3
3 Additional Info –
4 Building age 20+ yrs
5 High ceiling Y/N
6 Carpeted floors Y/N
7 Pin up boards Y/N
8 Curtains Y/N
9 Air Conditioning unit Y/N
10 Projector Y/N
11 Bare walls Y/N
12 Large Windows Y/N (new SINGLE GLAZED; 1 wall=1/2 height, other= ¼ height)
13 Building Material – fibrolite Y/N
14 Fans Y/N
15 Open door (or folding) to adjacent classroom Y/N
16 Concertina wall or partition to another room Y/N
17 Artwork suspended from ceiling Y/N
18 Child with hearing impairment Y/N
19 FM system in use (individual or classroom) Y/N
20 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
21 Acoustically treated ceiling Y/N mix of old material (40 % modern panels)
22 Acoustically treated walls Y/N (80 %)

Amb. Noise x 1 = 37.6 RT = 0.47

Bkgd. Noise x 3 = 45 STI = 0.72

C.18 ROOM 18 TRAD 7

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 18
DECILE RATING: 5
TYPE OF CLASSROOM TRAD

1 Number of children in classroom (28 in total) & Age 8,9
2 Classroom measurements L=9.27m W=3.55m H=3.55 m V=118.26m^3
3 Classroom photo
4 Additional Info –
5 Building age 50+ yrs
6 High ceiling Y/N
7 Carpeted floors Y/N
8 Pin up boards Y/N
9 Curtains Y/N
10 Air Conditioning unit Y/N (radiators)
11 Projector Y/N
12 Bare walls Y/N
13 Large Windows Y/N (single glazed 3/4 wall=1/2 height, other= ¼ height)
14 Building Material – brick Y/N exterior bricks, on solid concrete footing
15 Fans Y/N
16 Open door (or folding) to adjacent classroom Y/N
17 Concertina wall or partition to another room Y/N
18 Artwork suspended from ceiling Y/N (small line)
19 Child with hearing impairment Y/N
20 FM system in use (individual or classroom) Y/N
21 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
22 Acoustically treated ceiling Y/N mix of old material (50 %)
23 Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 34.4 RT = 0.40

Bkgd. Noise x 3 = 47.1 STI = 0.66

C.19 ROOM 19 TRAD 8

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 19
DECILE RATING: 5
TYPE OF CLASSROOM TRAD

1 Number of children in classroom (30 in total) & Age 8,9
2 Classroom measurements L=9.27m W=3.55m H=3.55 m $V=118.26m^3$
3 <u>Additional Info</u> –
4 Building age 50+ yrs
5 High ceiling Y/N
6 Carpeted floors Y/N
7 Pin up boards Y/N
8 Curtains Y/N
9 Air Conditioning unit Y/N (radiators)
10 Projector Y/N
11 Bare walls Y/N
12 Large Windows Y/N (single glazed 3/4 wall=1/2 height, other= ¼ height)
13 Building Material – brick Y/N exterior bricks, on solid concrete footing
14 Fans Y/N
15 Open door (or folding) to adjacent classroom Y/N
16 Concertina wall or partition to another room Y/N
17 Artwork suspended from ceiling Y/N (small line)
18 Child with hearing impairment Y/N
19 FM system in use (individual or classroom) Y/N
20 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
21 Acoustically treated ceiling Y/N mix of old material (50 %)
22 Acoustically treated walls Y/N (100 %)

<u>Amb. Noise x 1</u> = 34.6 <u>RT</u> = 0.41

<u>Bkgd. Noise x 3</u> = 46.1 <u>STI</u> = 0.6

C.20 ROOM 20 TRAD 9
ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 20
DECILE RATING: 5
TYPE OF CLASSROOM TRAD

1 Number of children in classroom (28 in total) & Age 8,9
2 Classroom measurements L=9.27m W=3.55m H=3.55 m V=118.26m
3 Additional Info –
4 Building age 50+ yrs
5 High ceiling Y/N
6 Carpeted floors Y/N
7 Pin up boards Y/N
8 Curtains Y/N
9 Air Conditioning unit Y/N (radiators)
10 Projector Y/N
11 Bare walls Y/N
12 Large Windows Y/N (single glazed 3/4 wall=1/2 height, other= ¼ height)
13 Building Material – brick Y/N exterior bricks, on solid concrete footing
14 Fans Y/N
15 Open door (or folding) to adjacent classroom Y/N
16 Concertina wall or partition to another room Y/N
17 Artwork suspended from ceiling Y/N (small line)
18 Child with hearing impairment Y/N
19 FM system in use (individual or classroom) Y/N
20 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
21 Acoustically treated ceiling Y/N mix of old material (50 %)
22 Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 35.3 RT = 0.50

Bkgd. Noise x 3 = 51 STI = 0.64

C.21 ROOM 21 TRAD 10

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 21
DECILE RATING: 5
TYPE OF CLASSROOM TRAD

1 Number of children in classroom (22 in total) & Age 6,7
2 Classroom measurements L=9.27m W=3.55m H=3.55 m V=118.26m^3
3 Classroom photo
4 Additional Info –
5 Building age 60 yrs
6 High ceiling Y/N
7 Carpeted floors Y/N
8 Pin up boards Y/N
9 Curtains Y/N
10 Air Conditioning unit Y/N (radiators)
11 Projector Y/N
12 Bare walls Y/N
13 Large Windows Y/N (single glazed 1 wall=1/2 height, other= ¼ height)
14 Building Material – brick Y/N exterior bricks, on solid concrete footing
15 Fans Y/N
16 Open door (or folding) to adjacent classroom Y/N (sound ingress under closed door adjacent room
17 Concertina wall or partition to another room Y/N
18 Artwork suspended from ceiling Y/N (small line)
19 Child with hearing impairment Y/N (x1 bilateral mod. SNHL + ESOL)
20 FM system in use (individual or classroom) Y/N
21 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
22 Acoustically treated ceiling Y/N mix of old material (50 %)
23 Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 35.3 RT = 0.56

Bkgd. Noise x 3 = 45.5 STI = 0.6

C.22 ROOM 22 TRAD 11

ACOUSTIC TESTING CLASSROOM CHECKLIST

NAME OF SCHOOL 22
DECILE RATING: 5
TYPE OF CLASSROOM TRAD

1 Number of children in classroom (24 in total) & Age 9,10,11
2 Classroom measurements L=8.59m W=7.20m H=3.39 m V=209.82m^3
3 Classroom photo
4 Additional Info –
5 Building age 50 yrs
6 High ceiling Y/N
7 Carpeted floors Y/N
8 Pin up boards Y/N
9 Curtains Y/N
10 Air Conditioning unit Y/N
11 Projector Y/N
12 Bare walls Y/N
13 Large Windows Y/N (single glazed 1/2 wall=1/2 height, other= ¼ height)
14 Building Material – brick Y/N Fibrolite
15 Fans Y/N
16 Open door (or folding) to adjacent classroom Y/N
17 Concertina wall or partition to another room Y/N
18 Artwork suspended from ceiling Y/N
19 Child with hearing impairment Y/N
20 FM system in use (individual or classroom) Y/N
21 Building is prefab (raised above ground on supports) – noisy under footfall Y/N
22 Acoustically treated ceiling Y/N old material (100 %)
23 Acoustically treated walls Y/N (100 %)

Amb. Noise x 1 = 36.5 RT = 0.39

Bkgd. Noise x 3 = 48.3 STI = 0.68

APPENDIX D: *I-PAD CALIBRATION*

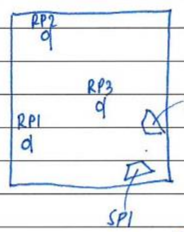
Marshall Day Acoustics Calibration report for 'Sound-Out' App on I-Pad

Sound Insulation Test

MARSHALL DAY Acoustics

JOB	Sound Out App (iPad)		
LOCATION	South (2-desk) office		
JOB No.	–	ENGINEER	AJ
DATE	7·9·18	TIME	

SLM B & K	CALIBRATOR		ROOM	PARTITION
2260: 2034412 2250: 3010261 ✓	4231: 2574264 4231: 1882775 4231: 3004051 ✓	Cal. before: 0·06 Cal. after: 0·04	DIMENSIONS	DIMENSIONS



DETAILS	L1	L2	B/G	RT					
M001 (Source position 1) – A weighted value from 100 Hz – 4 kHz									
"Background" RP1	50								
RP2	47								
RP3	49				(49 – avg. of 3 via SoundOut app.)				
"Ambient"	30				(34)				
$T30_{400-1.25kHz}$ "Reverberation time"	0·51	sec.			(0·46)				
M002 (Source position 2) RP1	57								
RP2	57								
RP3	59								
"Ambient"	31								
$T30_{400-1.25kHz}$ "Rev. time"	0·51	sec			(0·47)				

– MDA (B & K)
– Sound Out

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